WATER & SEWAGE WORKS

REFERENCE NUMBER

SEPTEMBER 15
1959

Water & Sewage Works Presents It's 1959 Reference Number

For the 26th time
Water & Sewage Works is
publishing a Reference Number.

This 1958 Reference Number
is issued with the hope of the
publisher and the editor that it will
be a useful text and information work in this field.

This Reference Number,
like its predecessors, is a reference
book or "manual" in the field of water sup-
ply and sewage disposal; it is a manual which
is revised and updated each year with the most im-
portant technical matter published in the previous year.

Each Reference Number
is, therefore, a single place to
find the best and latest material on the
field covered, for current and future reference.

Many technical articles
do not become outdated for several years,
and therefore, subscribers should retain at least the
past four Numbers, in order to have a complete "library".
To aid the reader, each Number contains a consolidated index
covering the past four issues as well as the current issue. For
the benefit of new subscribers, this issue contains some basic material
charts. and data, used in previous issues.

All subscribers
to Water & Sewage Works receive
the Reference Number without extra charge.

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WATER & SEWAGE WORKS

reference number

* SEPTEMBER 15, 1959

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INTRODUCTION

THERE ARE a number of valid reasons for covering the subject of water and sewage works practices in the same volume. That this is true is evidenced by the increasing trend of municipalities to place the management of both water and sewage facilities in one department or under one man. Latest figures developed from a survey of all the states shows that an average of nearly 65 per cent of the communities follow this practice.

Among the factors common to both water and sewage are hydraulics, physical and chemical treatment problems, and colloidal properties of water. Sewage is the used water supply of a community and the management of both are municipal functions, except in a few instances.

Because of this "oneness' of water and sewage treatment, it is both possible and desirable to adopt the format and outline used in this reference work.

In the management of both water and sewage facilities, there are similar problems of financing, office management, public relations, policy and safety.

Functional Operations

In this reference text, the following subjects are treated as common to both water and sewage and are therefore considered as functional operations: Pumping, electricity, flow measurement, instrumentation and control, chemical handling and feeding, sedimentation, corrosion control and laboratory control.

There are many other phases of water and sewage works practices that have elements of simularity and oneness. For example, water works have distribution systems while sewage works have collection systems. Treatment of water and sewage often involves the same approach, as for example in chlorination. The detailed operations of water and sewage works, however, often have enough different factors involved that it appears desirable to treat these details separately. This is done in this text to the extent necessary for the best use of this reference work.

Water Works Operations

All water supply problems begin with the source of supply and source of supply involves the hydrologic cycle including evaporation, precipitation, transpiration, runoff and, of course, storage both on the surface and in ground water aquifers.

Distribution of water supplies includes not only the network of pipes throughout a community but also elevated storage, valves, hydrants, house services, metering and such operation problems as main laying and cleaning, loss of carrying capacity, pressure, etc.

The treatment of water will depend on its source (ground or surface) and its chemical content. Surface supplies usually will require sedimentation and chlorination as a minimum. If the surface water supply is turbid or colored, coagulation and filtration may also be required; and if tastes and odors are present, their removal is desirable. Surface waters may also be subject to softening and iron and manganese removal. Ground waters may be hard and thus require softening; they usually do not require filtration or coagulation and sedimentation unless iron and manganese removal is necessary. Tastes and odors seldom occur in ground waters. Miscellaneous water works operations include fluoridation and maintenance.

Sewage Works Operations

While water work operations have problems of sources of supply, sewage works have a similar problem of effect of the waste on the receiving body of water. Stream pollution is important, therefore, particularly if the treated sewage reaches a body of water which serves as a water supply source.

Sewage treatment involves four basic processes: primary treatment, secondary treatment, disinfection, and solids disposal. Primary treatment deals with the removal by mechanical or physical means of suspended matter in the sewage. Secondary treatment is a biological oxidation (or wet burning) process for the stabilization of dissolved and colloidal organic matter. Disinfection is employed to destroy disease producing and harmful bacteria.

The disposal of solids is a highly important factor in sewage treatment. Methods of disposal may consist of digestion and dewatering followed by drying or incineration. Drying may be on open beds or in furnaces. Ultimate disposal of the final solids left after treatment may involve filling low areas, barging to sea, or use as a soil conditioner depending on the treatment. All of these approaches to the problem are dealt with in this book.

Industrial Wastes

Today the subject of industrial wastes has become so broad and so important that it is a field of its own although still allied to water and sewage treatment. The problem of industrial wastes is particularly important to municipal sewage treatment when these wastes are discharged to city sewers for treatment with the municipal sewage. How to treat such wastes and how to charge industry for such treatment is quite important to municipalities.

Design and Construction

Almost without exception, every municipality has an interest in the problem of design and construction of both water and sewage facilities. Without doubt, the proper design of facilities must take into consideration the problems of operation, maintenance and safety.

Construction likewise is important to municipal officials and superintendents of both water and sewage works. Whether or not to own or rent equipment for laying mains or sewers or to hire the work done by contract is a decision important to the efficient operation of these works. Current articles of basic import to this subject are included in the Reference Numbers.

Engineering Fundamentals

Among the engineering fundamentals of importance to both water and sewage works are chemistry and bacteriology, hydraulics and mathematics. For this reason these "handbooks" published as an extra number of *Water & Sewage Works* include articles, diagrams, tables, and data of a basic importance to this field.

Bulletins and Catalogs

There is one thing that every person needs in the field of water supply and sewage disposal. That is information on where to find equipment and services that will perform a job or function desired. Such information is, of course, contained in the bulletins and catalogs which equipment manufacturers issue.

In order to inform the reader of where he can obtain this information, as well as what is available, these Reference Numbers include a section which contains brief summaries of such bulletins and catalogs.

For the aid of the reader a card is included by which he can easily request any number of these bulletins or catalogs. In this manner it is intended to increase the usefulness of this Reference Number of *Water & Sewage Works*.

Directory of State & Territorial Sanitary Engineers

and

U. S. Public Health Service Field Offices

Alabama
A. N. Beck
Chief Engineer & Director
Bureau of Sanitation
State Dept. of Public Health
Montgomery 4, Alabama

Alaska
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Territorial Dept. of Health
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Hartford, Connecticut

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Minneapolis 14, Minnesota

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Jackson 13, Mississippi

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Lincoln 9, Nebraska

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State Dept. of Health
Charleston 5, West Virginia

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Madison 2, Wisconsin

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Alaska
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Juneau, Alaska

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Phoenix, Arizona

Arkansas
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Little Rock, Arkansas

California
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1227 "O" St. Room 316
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414 State Office Bldg.
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Hartford, Connecticut

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Station B
Lansing 1, Michigan

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Water Pollution Control Commission
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Minneapolis 14, Minnesota

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State Board of Health
Jackson 5, Mississippi

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J. K. Smith, Exec. Secy
State Water Poll. Cont. Bd.
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Dept. of Public Health & Welfare
Jefferson City, Missouri

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State Board of Health
Helena, Montana

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State Stream Sanitation Committee
State Board of Health
Raleigh, North Carolina

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State Dept. of Health
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Portland 5, Oregon

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Sanitary Water Board
Department of Health
Harrisburg, Pennsylvania

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Secretary of Health
Department of Health
San Juan 18, Puerto Rico

Rhode Island
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Director of Health
Department of Health
Providence 2, Rhode Island

So. Carolina
W. T. Linton, Executive Secretary
State Water Pollution Control Auth.
Caugham Bldg.
Columbia, South Carolina

So. Dakota
Charles E. Carl
Secretary & Executive Officer
Committee on Water Pollution
State Dept. of Health
Pierre, South Dakota

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Director
Stream Pollution Control Board
Department of Public Health
Nashville 3, Tennessee

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State Health Officer
State Dept. of Health
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Austin 1, Texas

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Water Poll. Cont. Board
130 State Capitol Bldg.
Salt Lake City 1, Utah

Vermont
Rheinhold W. Thieme, Commissioner
State Water Conservation Board
Montpelier, Vermont

Virginia
A. H. Paessler, Executive Secretary
State Water Control Board
415 W. Franklin Street
Richmond 20, Virginia

Virgin Islands
Dr. Eric L. O'Neal
Commissioner
Department of Health
Charlotte Amalie, Virgin Islands

Washington
Art Garton, Director
Pollution Control Commission
408 Old Capitol Bldg.
Olympia, Washington

W. Virginia
Bern Wright, Exec. Secy.
State Water Commission
Charleston 1, West Virginia

Wisconsin
Theodore F. Wisniewski, Director
Committee on Water Pollution
State Office Building
Madison 2, Wisconsin

Wyoming
Director of Public Health
State Dept. of Public Health
Cheyenne, Wyoming

Interstate Agencies

Bi-State Agency
Lief J. Sverdrup, Chairman
Bi-State Development Agency
915 Olive Street
St. Louis 1, Missouri

Delaware River
James H. Allen, Exec. Secretary
Interstate Commission on
the Delaware River Basin
Broad Street Station Bldg.
Philadelphia 3, Pennsylvania

New England
Joseph C. Knox, Secretary
New England Interstate Water
Pollution Control Comm.
72 Tremont Street
Boston 8, Massachusetts
Interstate San. Comm.

Interstate San. Comm.

N. Y., N. J., Conn.
Thos. R. Glenn, Jr.
Director and Ch. Engr.
Interstate Sanitation Comm.
110 Wiliam Street
New York 7, New York

Ohio River
Edward J. Cleary
Exec. Dir. & Ch. Engr.
Ohio River Valley Water
Sanitation Comm.
414 Walnut Street
Cincinnati 2, Ohio

Potomac River
Ellis S. Tisdale, Director
Interstate Commission on
The Potomac River Basin
203 Transportation Bldg.
Washington 6, D. C.

Books and Reference Manuals

Suggested Library Material for Water and Sewage Works

by GEORGE E. SYMONS, Ph. D.

Consultant & Technical Editor, Larchmont, N. Y.

Title and Price (F=Free)	*Publisher*	*Author*

I. Books for All Water and Sewage Works

Book of pH ($6.00)	*The* Macmillan Co.	Weber
First Aid, Surgical and Medical 4th Ed. ($4.00)	Appleton-Century-Crofts, Inc.	Cole and Puestow
Glossary—Water and Sewage Control Engineering ($2.00)	ASCE, APHA, AWWA, FSIWA	
Handbook of Cast Iron Pipe, 2nd Ed.	Cast Iron Pipe Research Assn.	
Laboratory Manual for Chemical & Bacterial Analysis of Water and Sewage 3rd Ed. ($5.00)	McGraw-Hill Book Co.	Theroux, Malmann & Eldridge
Lime Handling, Application and Storage in Treatment Processes (F)	National Lime Assn.	Rudolfs
Modern pH and Chlorine Control, 14th Ed. (F)	W. A. Taylor Co.	Taylor & McCrumb
Pipe Friction Manual, 1954 Ed. ($1.75)	Hydraulic Institute	
Rural Water Supply and Sanitation, 2nd Ed. ($4.90)	John Wiley & Sons	Wright
Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 10th Ed. ($7.50)	APHA, AWWA, & FSIWA	
Water Conditioning Data Book, 4th Ed. (F)	The Permutit Co.	
Water for Industry ($3.75)	Am. Assn. for Advance of Science	Graham, Burrill, et al

II. Books for Large Water and Sewage Works

Civil Engineering Handbook, 4th Ed. ($17.50)	McGraw-Hill Co.	Urquhardt
Corrosion: Causes and Prevention, 3rd Ed. ($12.00)	McGraw-Hill Book Co.	Speller
Corrosion Handbook ($16.00)	John Wiley & Sons	Uhlig
Data Book for Civil Engineers, I—Design, 2nd Ed. ($16.75)	John Wiley & Sons	Seelye
Data Book for Civil Engineers, II—Specifications and Costs 3rd Ed. ($20.00)	John Wiley & Sons	Seelye
Data Book for Civil Engineers, III—Field Practice 2nd Ed. ($7.50)	John Wiley & Sons	Seelye
Elements of Water Supply and Waste-Water Disposal ($8.95)	John Wiley & Sons	Fair & Geyer
Engineering in Public Health ($9.50)	McGraw-Hill Book Co.	Babbitt
Flow Measurement and Control ($11.00)	*The* Macmillan Co.	Coxon
Freshwater Biology, 1918 Ed. ($12.00)	John Wiley & Sons	Ward & Whipple
Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works—Joint Comm. Rept. ($0.75)	ASCE, ABA, AWWA, APWA, NARUC, MFOA, IBAA, FSIWA	
Handbook of Applied Hydraulics, 2nd Ed. ($17.50)	McGraw-Hill Book Co.	Davis
Handbook of Chemistry and Physics, 40th Ed. ($12.00)	Chemical Rubber Co.	
Handbook of Chemistry, 9th Ed. ($12.00)	McGraw-Hill Book Co.	Lange
Handbook of Hydraulics, 5th Ed. ($10.00)	McGraw-Hill Book Co.	King
Hydraulic Tables 3rd Ed. ($4.50)	John Wiley & Sons	Williams & Hazen
Industrial Water & Industrial Waste Water, Continuous Analysis of, S.T.P. 130 1953 Ed. ($1.50)	Am. Soc. Test. Mtls.	
Introduction to the Bacteria 2nd Ed. ($7.50)	McGraw Hill Book Co.	Clifton
Mechanical Engineers' Handbook, Power Volume, 12th Ed. ($10.00)	John Wiley & Sons	Kent-Salisbury
Microbiology, 2nd Ed. ($7.50)	Appleton-Century-Crofts, Inc.	Kelly and Hite
Pipe Friction Manual—1954 Ed. ($1.75)	Hydraulic Institute	
Plane Surveying ($6.75)	John Wiley & Sons	Tracy
Practice of Sanitation ($8.00)	Williams & Wilkens Co.	Hopkins & Schulze
Public Health Engineering, Vol. I ($8.50)	John Wiley & Sons	Phelps
Public Health Engineering, Vol. II ($5.50)	John Wiley & Sons	Phelps
Pump Handbook ($4.00)	*The* National Press	Finch
Pumps ($6.50)	McGraw-Hill Book Co.	Kristal & Annett
Rainfall and Runoff ($10.00)	*The* Macmillan Co.	Foster

Title and Price (F=Free)	*Publisher*	*Author*
Rosenau Preventive Medicine and Public Health ($)	Appleton-Century-Crafts, Inc.	Maxcy
Specifications and Law on Engineering Works ($6.50)	John Wiley & Sons	Sadler
Standards of the Hydraulic Institute, 10th Ed. ($4.75)	Hydraulic Institute	
Standard Mathematical Tables, 10th Ed. ($3.00)	Chemical Rubber Co.	
Standard Practices for Low and Medium Speed Stationary Diesel Engines, 4th Ed. ($5.00)	Diesel Engine Mfrs. Assn.	
Water Supply and Waste-Water Disposal ($16.00)	John Wiley & Sons	Fair & Geyer
Zinsser's Bacteriology, 11th Ed. (1951) ($12.00)	Smith & Conont	

III. Books for Small and Large Water Works

Fluoridation as a Public Health Measure ($4.50)	Am. Assn. for Advance of Science	Shaw, et al
Legal Guide for Water Works Men ($1.00)	Case-Shepperd-Mann Div., R.H.	Donnelly Co.
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co.	Hirsch
Manual for Water Works Operators, 3rd Ed. ($5.00)	Tex. Wat. & Sew. Wks. Assn.	Billings, et al
Operation of Water Filtration Plants of Mechanical Gravity Type—Bul. No. 484 ($1.00)	San. Eng. Div., No. Car. St. Board of Health	
Taste and Odor Control in Water Purification, 2nd Ed. (F)	Industrial Chemical Sales Div., W. Va. Pulp & Paper Co.	
Water Supply and Treatment, 8th Ed. ($2.00)	National Lime Assn.	Hoover-Riehl
Water Works Operation ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Water Works Questions and Answers ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	

IV. Books for Small and Large Sewage Works

Compressed Air Handbook, 2nd Ed. ($8.00)	McGraw-Hill Book Co.	
Control of Sludge Quality ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Controlling Roots in Sewers, Spec. Rept. No. 5 ($1.00)	Am. Pub. Wks. Assn.	
Handbook of Cast Iron Pipe, 2nd Ed. (F)	Cast Iron Pipe Research Assn.	
Laboratory Control of Sewage Treatment ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Manual for Sewage Plant Operations, 2nd Ed. ($6.50)	Tex. Wat. & Sew. Wks. Assn.	Billings, et al
Manuals of Practice (I-9)	Fed. Sew. & Ind. Wastes Assn.	
Practice of Sanitation ($8.00)	Williams & Wilkins	Hopkins & Schulze
Principles of Sewage Treatment, 4th Ed. ($1.25)	National Lime Assn.	Rudolfs
Recent Developments in Chlorination Practice, Spec. Rept. No. 9 ($1.00)	Am. Pub. Wks. Assn.	
Sewage Treatment, 2nd Ed. ($7.50)	John Wiley & Sons	Imhoff & Fair
Sewage Works Guide ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	

V. Books for Large Water Works

Fresh Water Algae of the U.S., 2nd Ed. ($13.00)	McGraw-Hill Book Co.	Smith
Ground Water ($10.00)	McGraw-Hill Book Co.	Tolman
Hydroelectric Handbook, 2nd Ed. ($17.00)	John Wiley & Sons	Creager & Justin
Hydrology ($7.50)	John Wiley & Sons	Wisler & Brater
Index to Journal AWWA— 1940-55 ($4.50) 1940-55 ($4.50)	Am. Wat. Wks. Assn.	
Ion Exchange Resins, 2nd Ed. ($11.00)	John Wiley & Sons	Kunin
Laboratory Control of Water Purification ($4.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Manual of Water Works Accounting ($4.00)	Am. Wat. Wks. Assn.	
Manual on Industrial Water, 1957 Ed. ($7.50)	Am. Soc. Test. Mtls.	
Microscopy of Drinking Water, 4th Ed. ($12.00)	John Wiley & Sons	Whipple, Fair & Whipple
NFPA Handbook of Fire Protection, 11th Ed. ($10.50)	National Fire Protection Assn.	
Physics of Flow Through Porous Media ($14.00)	*The* Macmillan Co.	Scheidegger
Public Water Supplies, 4th Ed. ($7.75)	John Wiley & Sons	Turneaure & Russell
Survival and Retirement Experience with Water Works Facilities ($3.00)	Am. Wat. Wks. Assn.	
The Quest for Pure Water ($5.00)	Am. Wat. Wks. Assn.	N. M. Baker
Water Bacteriology, 6th Ed. ($5.25)	John Wiley & Sons	Prescott, Winslow & McCrady
Water Conditioning For Industry ($10.00)	McGraw-Hill Book Co.	Powell
Water Power Engineering, 2nd Ed. ($10.00)	The Macmillan Co.	Hammond
Water Quality and Treatment, 2nd Ed. ($5.00)	Am. Wat. Wks. Assn.	
Water Supply and Purification, 3rd Ed. ($7.25)	International Textbook Co.	Hardenbergh
Water Supply Engineering, 5th Ed. ($8.75)	McGraw-Hill Book Co.	Babbitt & Doland
Water Supply and Sewage, 3rd Ed. ($8.75)	McGraw-Hill Book Co.	Steel
Water Treatment for Industrial and Other Uses ($12.00)	Reinhold Book Division	Nordell

Title and Price (F=Free)	*Publisher*	*Author*

VI. Books for Large Sewage Works

American Sewage Practice—Vol. III—Disposal of Sewage, 3rd Ed. ($10.00)	McGraw-Hill Book Co.	Metcalf & Eddy
Biological Treatment of Sewage and Industrial Waste— Vol. I Aerobic Oxidation ($10.00)		
Vol. II Anaerobic Digestion ($11.00)	Reinhold Book Div.	McCabe & Eckenfelder
Disposal of Industrial Wastes Materials ($7.50)	The Macmillan Co.	So. Chem. Industry
Disposal of Radioactive Wastes ($3.50)	The Macmillan Co.	Saddington & Templeton
Index, Sewage Works Journal (1928-48) ($4.50)	Fed. Sew. & Ind. Wastes Assns.	Wisely & Symons
Index, Sewage & Industrial Wastes (1949-58)	Fed. Sew. & Ind. Wastes Assns.	
Industrial Waste Disposal Charges in Cities over 5000 Population, Spec. Rept. No. 18-S ($2.00)	Am. Pub. Wks. Assn.	Baffa, et al
Industrial Wastes, Their Treatment and Disposal ($9.50)	Reinhold Book Div.	Rudolfs, et al
Industrial Waste Treatment ($9.50)	McGraw-Hill Book Co.	Besselievre
Industrial Waste Treatment Practice	John Wiley & Sons	Gurnham
National Plumbing Code		
Recommended Minimum Requirements for Plumbing ($1.25)	U.S. Gov't Printing Office Am. Soc. Mech. Engrs.	ASA-A-40.8-1955
Sewerage and Sewage Disposal, 2nd Ed. ($12.00)	McGraw-Hill Book Co.	Metcalf & Eddy
Sewage Service Charges in Cities over 5000 Population Spec. Rept. No. 18 ($2.00)	Am. Pub. Wks. Assn.	Tatlock, et al
Sewerage and Sewage Treatment, 3rd Ed. ($6.75)	International Textbook Co.	Hardenbergh
Sewerage and Sewage Treatment, 7th Ed. ($8.75)	John Wiley & Sons	Babbitt
Stream Sanitation ($6.00)	John Wiley & Sons	Phelps
Uniform System of Accounts for Sewer Utilities ($5.00)	Fed. Sew. & Ind. Wastes Assns.	

VII. Technical Reports, Manuals, Bulletins and Reprints[1]

A. Useful in Both Water and Sewage Works

Chemical Lime Facts (F)	National Lime Assn.	
Conversion Factors for Engineers, 23rd Ed. (F)	Dorr-Oliver, Inc.	
Financing Water Works and Sewerage Works Projects ($2.00)	Mo. Wat. & Sew. Conf.	Summers
Flow of Fluids Through Valves, Fittings and Pipe, 1956 Ed. (F)	Crane Co.	
Flow of Water in Cast Iron Pipe (F)	Cast Iron Pipe Research Assn.	
Keep Sheets of B-I-F Industries, Inc. ($1.00)	B-I-F Industries, Inc.	
Manual on Chemical Feed Machines, 1953 Ed. ($2.00)	Mo. Wat. & Sew. Conf.	Schworm
Manual on Consumer Water Rates, Part 1, 1952 Ed. ($2.00)	Mo. Wat. & Sew. Conf.	Miller
Principles of Handling Chlorine (F)	*The* Chlorine Institute	Langworthy
Public Relations Manual for Water Works and Sewage Works Operators ($2.00)	Mo. Wat. & Sew. Conf.	Magill
Safety Manual ($1.50)	Am. Wat. Wks. Assn.	
Specifications for Stationary Chlorine Storage Installations (F)	*The* Chlorine Institute	
The Chlorine Manual (F)	*The* Chlorine Institute	

B. Useful in Water Works

Copper Sulfate in Control of Microscopic Organisms, 1954 Ed. (F)	Phelps Dodge Refining Corp.	Hale
Drinking Water Standards ($0.10)	Govt. Printing Office	
Fire Engine Tests and Fire Stream Tables (F)	Nat. Bd. Fire Underwriters	
Management Manual ($2.00)	AWWA	
Operation and Repair of Water Facilities in Civil Defense Emergencies ($0.25)	U.S. Govt. Printing Office	
Pamphlets on Story of Water ($0.05 to $0.10)	Am. Wat. Wks. Assn.	
Priceless Water is Your Business (F)	Johns-Manville Corp.	
Producers and Repackagers of Chlorine in U. S. (F)	The Chlorine Institute	
Reprints of AWWA Committee Reports and Standards (order by number from list of AWWA publications)	Am. Wat. Wks. Assn.	

(1) The U. S. Public Health Service, all State Health Departments, The Amer. Wat. Wks. Assn, Fed. Sew. & Ind. Wastes Assn., and most colleges of engineering have many manuals, bulletins, and reprints (at nominal prices) of interest to water and sewage plant operation. Also, equipment manufacturers offer free technical reprints on equipment and process operation in the fields of water supply and sewage disposal.

Title and Price (F=Free)	*Publisher*	*Author*
Silent Service Is Not Enough—Public Relations ($1.50)	Am. Wat. Wks. Assn.	
Water Chlorination, History, Development etc. (F)	The Chlorine Institute	Langworthy
Water, Make Sure You'll Have Plenty (F)	Cast Iron Pipe Res. Assn.	
Water Rates Manual ($1.25)	Am. Wat. Wks. Assn.	
Water Rate Structures in America—1940 Ed. ($0.25)	Pub. Serv. Comm. of Wisc.	
What Price Water ($0.10)	Am. Wat. Wks. Assn.	

C. Useful in Sewage Works

Copper Sulfate for Root and Fungus Control in Sanitary Sewers and Storm Drains, 1954 Ed. (F)	Phelps Dodge Refining Corp.	Hood
Engineering Solutions to Industrial Wastes Treatment Problems ($1.00)	Case-Sheppard-Mann Dept. R. H. Donnelley Co.	
Engineering Solutions to Sewage Treatment Plant Design Problems ($1.00)	Case-Sheppard-Mann Dept. R. H. Donnelley Co.	
Filtering Materials for Sewage Treatment Plants	ASCE	
How to Get Top Performance from Sewage Treatment Plants ($1.00)	Case-Sheppard-Mann Dept. R. H. Donnelley Co.	
Manuals of Practice Nos. 1,2,3,4,5,6 (various prices)	Fed. Sew. Ind. Was. Assn.	
Report of Committee of Great Lakes—Upper Mississippi River Board of State Sanitary Engineers—Bull. No. 42 ($1.00)	N. Y. State Health Dept.	
Sewage Treatment Plant Design ($7.00)	ASCE, FSIWA	
Uniform System of Accounts for Sewer Utilities ($5.00)	FSIWA	

Addresses of Technical Book Publishers

Publisher	*Address*
American Association for the Advancement of Science	1025 Connecticut Ave., N.W., Washington 6, D.C.
American Public Works Assn.	1313 East 60th St., Chicago 37, Ill.
American Society for Testing Materials	1916 Race St., Philadelphia 3, Pa.
American Society of Civil Engineers	33 West 39th St., New York, N.Y.
American Water Works Assn.	2 Park Ave., New York 16, N.Y.
Appleton-Century-Crofts, Inc.	35 West 32nd St., New York 1, N.Y.
B-I-F Industries, Inc.	345 Harris Ave., Providence, R.I.
Case-Shepperd-Mann Dept., R. H. Donnelley Co.	305 E. 45th St., New York 17, N.Y.
Cast Iron Pipe Research Assn.	Suite 3440, Prudential Plaza, Chicago 1, Ill.
Chemical Publishing Co., Inc.	212 Fifth Ave., New York 10, N.Y.
Crane Co.	836 So. Michigan Ave., Chicago 5, Ill.
Diesel Engine Manufacturers Assn.	1 No. La Salle St., Chicago 2, Ill.
Dorr-Oliver Inc.	Barry Place, Stamford, Conn.
Federation of Sewage and Industrial Wastes Assns.	4435 Wisconsin Ave., N.W., Washington 16, D. C.
Hydraulic Institute	122 E. 42nd St., New York 17, N.Y.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	230 Park Ave., New York 17, N.Y.
International Text Book Co.	Scranton 15, Penna.
Johns-Manville Corp.	22 E. 40th St. New York 16, N.Y.
John Wiley & Sons, Inc.	440 Fourth Ave., New York 16, N.Y.
McGraw-Hill Book Co.	330 West 42nd St., New York 36, N.Y.
Missouri Water and Sewerage Conference	State Office Bldg., Jefferson City, Mo.
National Board of Fire Underwriters	85 John St., New York 38, N.Y.
National Fire Protection Assn.	60 Batterymarch St., Boston 10, Mass.
National Lime Association	925 Fifteenth St., N.W., Washington 5, D.C.
North Carolina State Health Dept.	Raleigh, No. Carolina
N.Y. State Health Dept.	Albany 1, N.Y.
Phelps Dodge Refining Corp.	300 Park Ave., New York 22, New York
Public Service Commission of Wisconsin	State Office Building, Madison, Wis.
Reinhold Book Division	430 Park Ave., New York 22, N.Y.
Texas Water and Sewage Works Assn.	2202 Indian Trail, Austin, Tex.
The Chemical Rubber Co.	2310 Superior Ave., Cleveland 14, Ohio
The Chlorine Institute	50 East 41st St., New York 17, N.Y.
The Macmillan Co.	60 Fifth Ave., New York 11, N.Y.
The National Press	850 Hansen Way, Palo Alto, Calif.
The Permutit Co.	50 West 44th St., New York 36, N.Y.
United States Government Printing Office	Washington 25, D. C.
W. A. Taylor & Co.	7300 York Road, Baltimore 4, Md.
Williams & Wilkins Co.	428 E. Preston St., Baltimore 2, Md.

Philosophy for Managers

by ABEL WOLMAN

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■ THE AD HOC COMMITTEE ON Public Information of the American Water Works Association presented a report reflecting in detail on the state of water works development in the United States. In this report, an appraisal was made of the difficulties now encountered in providing the best water service to the rapidly growing communities of the country. Among the obstacles to providing maximum quality service, high significance is placed on the deficiencies of management, the public, and technologists.

The Committee lists as the major road blocks to improvement in water service: lack of public appreciation, lack of realization of the problem by water works people themselves and lack of prompt planning for growth.

The U. S. Setting

Before attempting to evolve a philosophy for water works managers, it is well to spell out the setting in which such a philosophy may be expected to prevail. This setting likewise has been briefly reviewed, at least in part, by the American Water Works Association [2] and is paraphrased by the author (See Box).

In addition to the concrete characteristics of the present public water supply scene, even the amateur observer has become aware of the changing structure and the behavior of the people of the United States. This country is now confronted with 15,000 local governments, operating in 174 metropolitan areas, which include their surrounding cities of 50,000 or more population. As a matter of fact, most of the nation's increase in population since 1950 has occurred chiefly in the suburban portions surrounding the central cities. Historical solutions and principles governing water works development have not always proven to be appropriate to the new geographical and cultural developments. If it is recalled that about three-fifths of the nation's population now resides within such areas, one can no longer assume that the hand-to-mouth development on an inner core urban basis will always work. The trend here delineated gives no promise of cessation. It must be accepted, therefore, as the kind of development within which the water works manager must function. A recent Congressional Committee Report[3] apty describes this new urban pattern as "sprawling, still indecisive, and transitionally inefficient—but definitely new.—The process (of urbanization) has by no means run its course—indeed it promises to accelerate under the impact of the new Federal Interstate Highway System which will build 6700 miles of limited-access freeways in United States urban areas. The further explosion of our cities along these major highways —already experienced in Boston and some other cities—is a foregone conclusion."

The ultility problem posed by exploding areas, ribbon development, "skip-jump" subdivisions and complete disregard for political boundaries represents one of the major challenges of the past century to the majority of water works managers. Past attempts to fit these curious growth patterns into the straight-jackets of municipal design and finance have been singularly ineffective.

What Are The Answers

Questions urgently requiring answers, within this new setting[4] :

1. How many people will be served by our public water systems 25 years from now?

2. How much of a growth will there be in water requirements in the next 25 years?

3. Is there a real problem now, or a possibility that a water shortage will develop in the future, or will there be an adequate supply for all necessary purposes?

4. How far can a city afford to go for its water supply?

SETTING FOR PHILOSOPHY

1. Some 18,000 water works function in the United States, each dominantly controlling the present and future welfare of the community.

2. Water for domestic, commercial and industrial supply is vital to urban communities.

3. Adequate water supply facilities are absolutely essential to the growth of our country.

4. A country-wide survey of water utilities, both publicly and privately-owned, indicates that:

a. One out of five is deficient in supplies.

b. Two out of five are deficient in transmission capacity.

c. One out of three is deficient in pumping capacity.

d. Two out of five are deficient in treatment capacity and very many need treatment facilities not now installed to provide the quality product desired by consumers.

e. Ground and elevated distribution storage show deficiencies of 29 per cent and 43 per cent, respectively.

f. Distribution system improvements are required in 57 per cent of the water systems.

g. Many systems need to undertake measures to place them on an improved business basis.

5. Present systems are deficient to meet present demands. Those demands are high and will continue to grow. Water systems must be kept in balance with those growing needs.

6. Water utilities have planned and budgeted water system improvements totaling over $600,000,000 for 1958.

7. Water works projects needed to provide balanced systems to meet the growing needs of each community will cost billions of dollars.

8. Most local water supply system improvements can be undertaken and financed locally and will provide long-term public benefits without creating inflationary pressures.

5. Is pollution of water sources to be permitted to jeopardize the public water supplies and whose business is it to see that pollution is kept under control?

6. How can water utilities, the most essential of all community services, increase the public appreciation of their contributions toward better living?

7. Finally, as the solution of all water problems depends upon adequate and sound financing, on what basis should water charges be computed?

As Howson points out, all of these questions are simple repetitions of the familiar questions to which water works managers have been perennially exposed. Certain fundamental differences in solutions appear, however, in attempting to respond to the challenge of these questions. The country now supports millions of people who stemmed from urban areas and who for half a century have become accustomed to the utility services which public and private units have provided. With their movement into areas with larger lot sizes, with less accessibility to water sources, with characteristics of fringe growth and with developments so often controlled by cheapness of land and by rapidly extending highways, new modifications of old problems emerge.

Basis for Philosophy

Regardless of the above circumstances, people are unwilling to accept primitive facilities and are not satisfied with arguments that modern engineering cannot and perhaps should not meet their desires. The water works manager, therefore, if he has not already done so, must find answers to these problems rather than maintain a stoical status quo. Such an orthodoxy of position deprives him of maintaining or acquiring the imagination and leadership which the community undoubtedly expects of him or of someone who will replace him.

One is aware that such reorientation implies redefinition of purpose, of engineering method, of fiscal evaluation and adjustment, and of the gradual evolution of novel experimental approaches to solving these problems.

In the light of these observations on the present way of life of the American people, it is now possible to define somewhat more specifically the areas of a manager's responsibility. By such definition, philosophy, as a guiding principle, will emerge.

Foresight

Perhaps the major obligation of a water works manager is to stand aside from the present and look at arm's length at the immediate and the remote future. He must be in a position to accept the emergency scene and its strange demands on and in relation to water service. It is in this obligation that the widest range of his imagination may be demonstrated. In viewing such a vista, he must escape the heavy hand of the orthodox past, except where it offers him a sound basis for imaginatively exploring the future. An imagination, tempered by the realities and practicalities of the market place, is the area where perhaps his greatest potential lies.

Some examples of such pressing questions are here noted. The water consuming habits of people and industry have not yet been completely explored and certainly not measured in detail. The literature is filled with assumptions of consumer behavior and with parallel assumptions as to the part which the water works developer may play in meeting or combatting this behavior.

Committees of water works practioners are increasingly exposing these areas of assumption to quantitative diagnosis and suggesting furthermore that sound appraisal of the underlying bases of these assumptions should be made in the field as rapidly as possible.

One such area, of course, is the familiar suggestion that summer sprinkler necessities cannot be met, except at undue expense in distributing system reinforcements. Is this true and if true, what are the parameters and what are their quantitative features? Studies in this area alone are amazingly meager and fragmentary.

Much has already been made of the necessity for a new look, both broadly and deeply, at the whole fiscal basis for water works development. Case histories abound in the United States of where water works managers, through ostrich-like appraisals of current problems, have retarded development and have in fact invited chaotic development.

Much of this attempt to stem the tide of growth (which incidentally still remains a major indoor sport for some water works managers) has its origin in the desire to maintain a tax base within municipal boundaries, to resist growth beyond the boundaries, to pursue rules of extension which have outlived their appropriateness, to gain little or no support from regulatory agencies for a reappraisal of the problem and to clinging to the eternal hope that somehow or another the future will be more peaceful and familiar in demands than the immediate past.

The history of almost every major

water area in the United States presents one or more of the above characteristics. It would be interesting on some future occasion to determine why this policy of resistance has so persistently prevailed. Water works literature has long made available to the water works manager alternative fiscal principles dating back to the proposals by Snow in New England, by Morse and Wolman in the Maryland area, by the Joint Committee of the American Society of Civil Engineers and the Section of Municipal Law of the American Bar Association, and more recently by Richard Hazen. Each of these reviewers of fiscal policy has emphasized for many years the necessity of imposing part of the cost of water utilities on property owners, whose property is enhanced by the availability of water and sewer service, whether or not they immediately use the service. In addition, much water distribution extension in metropolitan areas is geared to future land development.

Population growth, from the geographical standpoint, in the last 20 years makes new reference to these principles virtually a necessity for every water works manager. This is particularly true where necessary design and construction for the future consumer imposes an undue burden upon the present user, if capital costs are recaptured only by means of consumption charges. True regional water supply development, so characteristic of our rapidly evolving urban areas, cannot proceed within the confines of fiscal perspectives of the old municipality. The mere doubling of water rates to outside consumers by no means goes to the roots of this issue, as the last ten years' experience well demonstrates.

From a political standpoint, it is equally clear that the future will become more complicated rather than less. If the manager hopes to see in the future less prospect of psychological disturbance in meeting his responsibilities, he is foredoomed to disappointment.

Functional Operations

In the areas of design, construction, operation, and maintenance, the water works profession has an enviable record of which to be proud. That record is likely to be sullied, if the profession does not move with great rapidity to forestalling the deficiencies in all these areas which new growth is creating at high speed.

Here, again, the manager is confronted with the necessity of adjustment in sights. The ingenuity required in these functions is no less striking than in the solution of fiscal and economic problems of utility service.

Some water works purveyors are already demonstrating, not only an awareness, but imaginative answers to these growth problems. Both private and public service is being designed and constructed, which in fact skips geographical sections, while developing under single management satellite sources and distribution systems, geared to be linked through appropriate connection with existing systems as time and as growth may later demand or justify. Even rural areas are now being served with economy in the Washington Suburban Sanitary District.

Public Relations

There are distinguished examples of water works managers in the United States who have demonstrated superb capacity for public relations. They are unfortunately few in number. A recent review [5] of this situation leads to the conclusion: "it seems that the problems of management and administration have not been a serious concern of the water utility profession."

In other words, great concentration and successful implementation has gone into the utilization of material resources and relatively little into the relationship of such material resources to human problems.

The skill which some have shown in bridging this gap apparently has not infected large numbers of water works managers.

The almost universal desire to avoid political entanglement has virtually precluded many excellent technologists from taking a desirably effective position in the community. Politics remains to most as anathema, rather than as the art of governing people. In this essential art in a democracy the water works manager must find a significant daily part.

Organization

No successful management operation results from only the manager himself. Success is peculiarly the result of total organization. It is not the simple drafting of an organization chart, but is the characterization of an indefinable spirit of public service. Indefineable as that spirit is, it is quickly apparent in almost any contact with water departments or companies. The skill of a manager in having an all pervasive influence in the entire organization of public service is as important as it is elusive and rare.

Legal Assistance

Increasingly the problems of water service will create problems in law. The skillful guidance of the lawyer, more and more familiar with water service, becomes a major necessity to the manager. Again, awareness of the problems to be encountered, the issues to be met and the preparations for such encounters is being rapidly extended. They impose, therefore, additional responsibilities which historically were either simple or sometimes nonexistent.

Conclusion

One cannot review this entire scene without a strong sense of the difficulties involved in any water works manager's life. A rehearsal of the vices which he has developed over the years of his experience and of the virtues which the future may demand of him can only lead to a feeling of complexity and perhaps even of frustration.

In spite of this, however, the reflective manager will undoubtedly emerge from the present crises with a broader concept of his responsibilities and a deeper consciousness of the skills required for their implementation in order to make the most successful contribution to society. No simpler definition of a philosophy appears either possible or desirable. If such a philosophy must be firmed up in simple terms it has in fact been anticipated by the American Water Works Association in the slogan "Good water, the life blood of your community." The slogan itself virtually defines the limitless nature of the obligations of the water works manager.

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Planning Water Supply Resources

by JOHN E. KIKER, JR.,
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■ THE ENTIRE COUNTRY was made aware of the importance of water when New York City was threatened with a serious water shortage. In 1950, "Shaveless Thursdays" came into being as a means of dramatizing the predicament of the city, and penalties were imposed for the unauthorized use of water.[1]

In some respects the situation that occurred in New York illustrates the kind of thing to guard against in the planning and development of water supply resources. The reason for selecting New York City in this case as an example of what not to do, is because it might be the last place where you would expect a shortage to occur. Furthermore, its water history has been a series of crises, with new sources coming into operation just as consumption caught up with and passed the supply.[2] Some Florida cities and metropolitan areas have had similar experiences.[3] Although New York City has had good engineering advice, the reports and warnings of its engineers were not headed until it was too late to forestall the impending shortage. Construction of the Delaware Aqueduct did not start until 1937, although it was recommended in 1927 and reports on it were published in that year.[4]

The New York Experience

The plan for developing the new supply was not approved by the City Board of Estimate and the State Water Power and Control Commission until 1929. The development was further delayed by litigation when the State of New Jersey applied to the Supreme Court of the United States to enjoin the State and City of New York from diverting any of the waters of the Delaware or its tributaries. The Supreme Court decision permitting the City to divert up to 440 mgd was given on May 25, 1931. By that time the country was having a serious depression. This was considered the reason for a delay of about seven years, according to a report of an Engineering Panel on Water Supply[5].

In any case, work which finally began on the project in 1937 had to cease in 1943 because of the impact of World War II and the shortage of men and materials. It did not resume until 1946, making a total delay of some 14 years. The water shortage of 1950 was caused by a drought in 1949. Under ordinary circumstances, the project should have been completed about eight years before the shortage occurred. Since 1950, numerous water shortages have occurred throughout the nation.

Interest in Florida

In 1953, the New York story was referred to in an editorial prompted by a relatively minor accident in the state of Georgia. The editorial appeared in the *Florida Times Union*, under the caption "It's Too Late When the Tap Runs Dry." It explains the situation so well that it is worth repeating.[6]

"Water flowing from the tap has become such a dependable service that most of us now regard it as one of the absolutes. Because of this assumption, the rare failures in the service cause enormous difficulties and hasty adjustments to new conditions.

"Latest to be reminded of this were 400,000 of the residents of Atlanta, who were without water for a half hour when their main supply artery broke. Failure of electric services, gas lines, or heating systems can cause great discomfort and inconvenience, but failure of a water supply can make a city uninhabitable. Of all services and products supplied by utilities, water is the single one absolutely necessary to life."

"The public's tendency to consider the tap the source and think no further, is a dangerous one. Such thinking induced New York (the most modern city in the world) to postpone undertaking projects for a suitable reserve water supply. The city's resulting uncomfortable predicament a few years ago is well known.

"Bernard Baruch has told U. S. senators that in 53 years water will be more valuable than oil in the nation because of increases in industrial use, in individual consumption, and in population. Several areas of the country are already afflicted by drought and have experienced water shortages."

Florida Water Resources Study Commission

Florida has already made a start on preliminary studies which are necessarily in the proper planning and protection or conservation of its water resources. As directed by Chapter 29748 of the 1955 State Legislature, a Florida Water Resources Study Commission was formed in 1955. The commission made a comprehensive study of the physical, administrative, and legal aspects of water problems and water management in Florida[8].

As recommended by the Study Commission, the Board has regulatory powers which include the following functions:

a. To authorize the capture, storage and use of water, including flood waters, in excess of reasonable uses; and to authorize the diversion of such waters beyond riparian or overlying land; and

b. To establish reasonable rules for conservation of water in regions where diversion of surface or underground waters threatens to exceed the natural replenishment of such waters or to render them unfit for use by reason of salt water intrusion or other causes.

Certainly the granting of such powers is a step in the right direction, and if it functions properly, the Board will render a real service to the State of Florida. Of course, the actual planning of water resources to meet metropolitan expansion is a job for the consulting sanitary engineers, but an important function of the Department of Water Resources is to help in guaranteeing that a suitable water supply once developed will remain of satisfactory quality. The value of safeguards against salt water intrusion

from overpumping, for example, is readily apparent to almost everyone in sections of the state where ground water supplies have been ruined already by salt water intrusion.

Another very serious problem requiring careful planning and study in Florida is concerned with the contamination of ground water supplies from sewage discharging to sinkholes in porous limestone formations. An otherwise good water supply and municipal water softening plant had to be abandoned because of sewage contamination through a sinkhole in Lake City. And in 1948, dye placed in the sewage effluent from the University of Florida showed up ten hours later a mile and a half away in a well owned by the City of Gainesville.

Although the situation with which the City of New York has been confronted has many historic parallels in smaller metropolitan areas, and all metropolitan areas should take heed of such close calls as the one which occurred in New York, the political, economic, and engineering problems in the development of adequate metropolitan water supplies are in many respects different for each area or community. However, there are certain fundamental engineering procedures which are similar in most cases.

Estimates of Population and Water Consumption

Usually, the first step in the planning, design, or development of a water supply system is to predict the future water consumption. To make this prediction, it is desirable to examine and to estimate separately, population growths and per capita consumption rates. The product of these figures is the predicted total consumption.[5]

In order to make accurate estimates of future water consumption, an engineer must study all of the existing analyses and forecasts which he can uncover. There are a number of sources of information which may be helpful in estimating probable future populations. Among them are chambers of commerce, U. S. census reports, health department statistics, and estimates of school boards, power companies, and telephone companies. Often there are special reports and analyses, but the utiliziation of all such reports must be tempered with a considerable amount of judgment.

As everyone knows, Florida is experiencing a phenomenal growth. Its present population is estimated at 4,300,000. In five years the population is expected to increase by 33 per cent, to 5,800,000. A 75 per cent increase or a population of 7,500,000 is predicted in ten years. Of course different areas will grow at different rates, the prediction being 24 per cent in ten years for the middle northern part of the state (including Tallahassee, Gainesville, and a few other spots which will grow faster than the average) to 93 per cent for the East Coast, South, including Dade, Broward, and Palm Beach Counties of the so-called Gold Coast.

In other words, Florida is going to have more metropolitan areas, of which some will be developing much more rapidly than the average for the state as a whole. The problem of furnishing water to this rapidly increasing population is compounded with a rapidly increasing rate of consumption. During the past few decades the consumption of water has been increasing at a rate of about one gallon per person per year. It has been more rapid than that since World War II because of the increased use of water consuming devices in the home. Automatic dishwashers, automatic laundry machines, air conditioning equipment, garbage grinders, and other household appliances add considerably to the water consumption. The present consumption rate in Florida is estimated at 125 gpcd, while the national rate is about 145 gpcd. If we continue at the present annual rate of increase the per capita consumption in Florida may be in the neighborhood of 165 gpcd by the year 2000. These and other factors must be taken into consideration in the planning and development of our water supply resources.

Taking the nation as a whole, our industrial water requirements are expected to double by 1975. For Florida, the industrial requirements should increase at a much larger rate, or on a scale more comparable with that of its phenomenal growth in population. The effect of such an impact on water resources planning and development cannot be overestimated.

The second step in the water supply planning and development program for a metropolitan area should be that of making a thorough inventory of all available water resources. Some will suggest that this should be the first step — and well it should in some instances. Such was the case in studies recently completed on a water resources planning program in California where some estimates of water requirements have been out of date even before they were published. The situation in some parts of Florida is not far different from that in California, although Florida's water resources are much more adequate relatively than are those of California.[9] As with California, however, the rate of development in parts of Florida is so fantastic that it must be seen to comprehend it fully.

The third phase in the water supply planning program for a metropolitan area should be that of developing a master plan for supplying the water. And, finally, the plan must be put into effect. An engineer can produce excellent plans and reports, but these will be worthless if they rest on the shelf gathering dust.[10] Unfortunately this is what happens in many cases.

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Effective Management Through Organization

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Organization

Organization is a process of identifying and grouping work, of finding and delegating responsibility and authority, and of establishing relationships to enable people to work most effectively together.

The problems of organization involve people, the division of labor, the source of authority, and personnel relationships or teamwork. Delegation of both responsibility and authority is important to good organization.

To Revaluate Organization

There are four steps to be taken in any attempt to revaluate an existing organization:

1. Make a list of employees, titles and duties.
2. Group employees under supervisors
3. Group supervisors levels
4. Get employees to participate, ask them to list their jobs and what they do, daily, weekly, monthly.
   a. What do they do?
   b. Names or titles they get orders or instructions from?
   c. What suggestions or advice do they give—or receive?
   d. What reports do they prepare and who gets a copy?
   e. What reports do they receive and from whom?
   f. How do they use the information in reports received?
   g. Other facets or factors in the job?

Delegation

No one should try to do everything himself; an individual is only one man and can do only so much, to do more he must assign and delegate. The difficulties in delegation stem from (a) lack of faith in subordinates and (b) lack of communication and checks on delegation.

There is, of course, an obligation on the part of the delegatee to produce on assignment.

The three elements of delegation are:

1. Work or responsibilities involved.
2. What is authority that goes with delegation.
3. What is obligation or accountability of subordinate back to manager.

Among the problems of delegation are: the manager is not relieved of responsibility for the action of others; it is often hard for the manager to find the man to whom delegation should be made; and it is often hard for a manager to give up his pet preference for ways of doing things, but all managers should remember not to try to run a one man show.

Eight steps to successful delegation:

1. Look again at subordinates
2. Take the middle road—If you look over a man's shoulder, you smother his ingenuity; but if you don't look at all some difficulty may arise; proper guidance is the middle road.
3. Measure the job for the man.
4. Tell top management, too, about subordinates' potentials.
5. Tell your man where he stands; make him understand his responsibility.
6. Make the job worthwhile; make it challenging; give sub-ordinate a chance to grow.
7. Set standards high, but not out of reach.
8. Reward the man—with money, job satisfaction, a pat on the back.

How to ease your burden—Delegate these items:

1. Responsibilities hanging over from past operations.
2. Recurring routine details.
3. Routine decision making (this should be delegated by establishing written policies.)
4. Jobs that take big chunks of time.
5. Functions you are least qualified to handle.
6. Details you don't like—find some one who does.
7. Duties that tend to over-specialize you.

When you want to develop employees, delegate these items:

1. Tasks that add to job skills or mold attitudes.
2. Tasks that provide variety.
3. Tasks that contribute to job wholeness.
4. Jobs that provide challenge.
5. A sequence of jobs of increasing difficulty.

Management Questions

Here are 13 important management questions designed to help you appraise your own application of management principles. Ask yourself each question contemplatively and answer objectively. You can thus note specific areas for self-development.

1. Am I a general manager doing an overall management job? Or am I a technical specialist in one or two phases of my business?
2. Do I have specific goals for my organization for the next five years? For the next year? If so, what are those goals?
3. Do I have plans for action that will help me attain company and personal goals? If so, are they sufficiently clear and definite to provide guidance for me and my employees?
4. Are all recurring situations that require decisions in my business covered by clear policies? Are these policies in a form, preferably written, so that they are uniformly *understood* and *applied* by every key employee in the company?
5. Have I recently analyzed the functions and activities which must be performed to meet the goals of my organization?
6. Have the functions been grouped in accordance with good organization to eliminate gaps and duplications?
7. Have all functions been assigned to appropriate personnel? Are all activities being capably performed by me and by my employees? Does each one understand thoroughly his authority and responsibility?
8. Am I providing leadership through ideas in my organization?
9. Do I make decisions on the basis of all the facts? Do I unnecessarily duck making decisions or put them off?
10. Have standards of performance been set up for every element of my business affecting profits? Do I regularly check actual results against the standard?
11. Does my system of accounts and records indicate promptly when something is wrong? Does it help me to take remedial action *where* required, *when* required?
12. Am I systematically getting the benefit of the ideas that my employees have for improving our business? Do we operate effectively as a team in my organization, with interchange of ideas up, down, and across?
13. Do I have a systematic plan for management development—for myself and my key subordinates? Is the plan working?

Water Works Budget

for Akron, Ohio

by WENDELL R. LaDUE,
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■ THE AKRON WATER supply system includes 2 impounding reservoirs with a third under construction; considerable watershed land purchased in advance for future reservoir purposes; a treatment plant and pumping station delivering the water a distance of 11 miles to the city distribution system; a distribution system of almost 800 miles of mains; several repumpage districts with pumping stations and elevated storage. The water is delivered to about 80,000 consumers through services installed by the utility to the property line at the consumer's expense. Meters are furnished and installed by the utility without cost to the consumer.

The management of the Akron water utility is the Superintendent and Chief Engineer's responsibility. He reports to the Director of Public Service, who in turn reports to the Mayor. The funds of the utility are administered by the Director of Finance of the City and purchases are made by the City Purchasing Agent.

Budgeting Limitations

The budget is a plan of the expenditures to be incurred during a particular period and the income for financing them. Too often when laymen, and some water management officials, speak of "the budget," they neglect or ignore income, the second part of the consideration. Income is an essential item of the budget. Without it expenditures are meaningless.

The preparation and control of a budget requires a system of accounts. Such system will vary with each utility, depending upon the legal control under which the system operates, plus the manager's and local government's desire for detailed information. Therefore, only a brief outline of the Akron, Ohio accounting system will be given.

Budget making and budget control are subject to the many variations established by State authority and to which water works managers, and those trusted with control must conform.

Likewise, the fiscal officer (Finance Director) of the political subdivision determines many factors of the budget making—and for its control—to which the water works manager of the municipal plants must conform in order that the water works budget will conform to and complement the city budget. While some of these factors may seem minor, they are nevertheless numerous. With the usual political turn-over of fiscal officers (usually a political appointee) each with his own idea as to procedural details—the result is oftimes discouraging to water works managers who desire and need a continuing financial record of the management of the utility. Let us consider the following:

1. Is utility private or municipal?

   Private utilities by commissions are subject to state control of the rate structure. Consequently the budget control and accounting are closely supervised as to budget control and budget observance and accounting procedure.

2. Are municipal utilities under the same strict control as are the private utilities?

   This happens sometimes, even more closely and more often.

3. If municipal utilities are not under the same strict supervision as are the private utilities, state supervision will vary from an audit to detect illegal expenditures and the legality of the methods employed for financing them, to the submission of a report in the same form as is required of the private utilities.

With only general supervision by the state, local laws will require that the municipal utility budget tie-in with the city budget, principally because the ownership of the property and the backing for the investments for this property generally lie with the city's

credit. In some instances, Authorities may be established with independent fiscal responsibilties.

When the water utility's fiscal matters are a part of the city's financial pattern, the Water Works Manager's concern and responsibility for the financial aspect of the utility grows as the size and complexity of the utility increases. Often there is a tendency to restrict and detract from his responsibility by transfer of the commercial and financing functions to the City Finance and Purchasing.

Likewise, there may be a constant pressure in effect to divert the utility funds for non-utility purposes, and to the utility personnel to perform duties for "related" city work. In these cases, the water works manager must be on his guard to prevent the utility from being strangled and his ability impaired to operate the utility properly. In such cases, he has sufficient funds to function adequately.

Income Sources

Income may be derived mainly from four (4) sources:

1. Sale of Water—This is the main source of revenue. Likewise, it is a most unpredictable source, and to a great extent may be out of the control of the water works manager. In the mid-west, weather conditions in the summer affect sales of water as well as other commodities. A wet summer as well as a cool one, may cut deeply into the estimated income. Likewise, in an industrial city the general national economy, continuity of industrial production, and labor relations have considerable effect on the utility's income. The rate schedule, while subject to change, should assure and produce on an average, adequate funds over the fluctuations of a period of years. It is not feasible or reasonable to make frequent changes as is done in commercial business.
2. Reimbursement for Recoverable Expenses—This includes consumer services and possibly meters when furnished and installed for the property owner by the utility. Percentagewise this is relatively small (Perhaps 10-15%) and can be adjusted frequently to meet the changes in cost of these items without undue comment.
3. Miscellaneous — These include rents, inter-departmental sales and services, and interest on operating cash in bank or on unexpended bond funds, sale of materials, and other small items of other than water income.
4. Sale of Bonds—Premium and rate of interest reflects the expenditures required for interest and bond retirement payments.

Expenditures Incurred

Expenditures are divided mainly into four (4) classifications:

1. Operation and Maintenance—The item under this classification would seem to be clear. However, the manager must be on his guard in the interpretation of periodic expenses which some may consider "maintenance" and others as "replacement" to be charged to "outlay" in the absence of an actual depreciation reserve. For instance, water main rehabilitation by cleaning and lining.
2. Recoverable Expense—As noted under Income Item, these expenses for consumer services and meters are offset by reimbursement.
3. Plant Expansion—
   a. By Outlay from annual income from sale of water, this expenditure is a "pay-as-you-go" year by year safety valve use of periodic surplus funds over a fixed minimum "nest egg." It automatically provides a reserve for unusual expenses, or decrease in sales and forestalls a demand for a reduction in rates. It may be considered a depreciation fund for that part of the system for which bonds are not being retired as this money is being "plowed-back" into the system. Again it may be considered a bonus in the case of a system which does not need expansion or replacements. After all, are there any such? This bonus might be used for a rebate on one round of billing. This, however, is a dangerous provision as it might spark a drive for reduction in rates.
   b. Bond Fund Expenditures for plant expansion.
4. Capital Expense—
   a. Interest on bonds and notes sold for plant expansion and improvement.
   b. Bond and note retirement.

   Retirement of the bonded debt is essentially a depreciation item. When the bonds for a plant expansion—or replacement—are completely retired, the expansion is depreciated to its estimated life. Retiring bonds coupled with cash payments into a depreciation fund is a dual demand on the finances of the utility and cannot be justified.

Budgeting Procedure

After the budget is fixed, then the approved budget should be presented and accepted before the start of the fiscal year. Too often a water department budget is tied into and considered a part of the general city budget, resulting in a lag of as many as 3 months after the start of the fiscal year before acceptance. In this case, the utility works on month by month "temporary" budgets with the result that contracts for yearly supplies cannot be entered into until nearly one-half year has passed. Since the water utility budget should be entirely separate from the annual city budget which is dependent upon current tax rate, it would be helpful to have the utility budget approved and placed in operation in advance of the general city budget. When the city budget is presented for approval, then the utility budget could be incorporated as a single item without breakdown.

The preparation of the budget involves a review by the manager of the utility with the heads of the various departments using financial and operational statistics for the past several years, thereby forecasting the financial features of the coming year. This procedure involves statistics of water demand, increase in the number of services, need for system expansion and replacements, operational and maintenance costs, with specific knowledge of future wage schedules and materials costs.

With these factors determined, a trial balance is run. Following this, adjustments to bring Expenditures in balance with Income, bearing in mind

a possible use of a portion of the estimated cash surplus obtained at the start of the fiscal year. Arriving at a budget for the year and having it approved is only the start of the problem.

Accounting

A water works utility accounting system must be under the control of the operating manager. As previously noted, the accounting system should be such as to provide the manager with a month by month cash picture of the financial condition of the utility. Another very essential use of this cash accounting system is in a study for rate adjustment. In this connection, a continuing break-down of water consumption by different classes or volume of water used by different consumers in various areas served by the utility is not only of value in rate adjustment, but from the engineering viewpoint, in the study of distribution system expansion. In establishing a system of mechanical billing for my city, this information was provided in the design of the machine. Thus these continuing data are obtained as a product of the customer billing as well as a cash balance.

The funds on which the utility operates are derived solely from the sale of water, and from other operations of the utility. There is no reimbursement from taxes for "hydrant rental" or other sources. Likewise, the utility makes no contribution to the general City operation other than rent for its quarters in the muncipal building. State supervision of financial operations is limited to two-year check for errors or legality of payments.

The commercial section of the water department is divided into the following three subsections:

1. General customer activities except billing and collection.
2. Billing, collecting and control of all cash receipts of the utility. Meter reading is under the supervision of the distribution section. The receipt of all funds and the deposit of them with the finance department is the responsibility of this subsection. Akron has a sewerage service charge and the water department acts as an agent for the City in billing and collecting these funds. The utility is reimbursed for this service. The utility and the sewerage service funds are segregated.
3. General accounting including purchase and accounting of material, payrolls, rents and miscellaneous bills. It does not include billing and collection for sale of water and for service installation.

Billing, Collection and Control of Receipts

The 80,000 consumers are billed quarterly, bills carry a "net" and "gross" amount. The gross amount applies 20 days after the due date of the bill. The city is divided into 9 districts with bills dated 11th, 21st and last day of each month.

The ledger card system for consumer's accounts is used as it is desired to maintain a continuing record of a given account easily available for reference. This is considered very valuable as an aid for good consumer relations. Each sheet contains designation for size of meter which aids the biller to determine the minimum bill for the given service. The filing of the ledger cards in a vertical offset file provides a means for locating unpaid accounts easily and rapidly.

Accounting Office Procedure

Obviously the accounting starts with the meter reader, and his route book is the initial part of the accounting system. Each route book is the primary unit of control. It represents one work day for the reader, and it is the primary unit of financial control. This separation into as much as 450 units reduces the time required to keep the ledger and teller records in balance. The meter reader does not compute the quantity to be billed.

To reduce the need for second trip of the reader to those houses where readers could not enter, a card is left at the door with a request for the occupant to read the meter and send the card to the office. A list of missed readings is in the route book when it is sent to the office. The route book when received is reviewed for stopped meters and as reading post cards are received, the readings are entered on the reader's sheet. Shortly before the route is ready for billing, work orders

Major Classifications General Accounting System

Income

- A. Sale of Water
- B. Reimbursement for Recoverable Expense
  1. Service Installation
  2. Paving Restoration due to service installation
  3. Curb meter installation
- C. Miscellaneous
  1. Rent
  2. Work done for others
  3. Sale of material
  4. Miscellaneous
- D. Rotary or Inventory

NOTE: Each account is further detailed as deemed necessary. The administration account includes not only the ordinary accepted administrative charges, but engineering, commercial office, and meter reading expense. H2—New Service installations; H3—Miscellaneous work for others; J1—Curb meter installations; K1—Miscellaneous. Under outlay are: G1H—Main extensions; G1I—Other system improvement; G1F—Water meters; and G1A to E—Miscellaneous. Under capital are: M1A—Interest; M1C—Bond retirement; Rotary or Inventory.

Expenditures

Operation and Maintenance

- A1 Salaries
- A3 Office Equipment
- A4 Office Supplies
- A5 Miscellaneous
- A6 Auto Operation
- A7 Workmen's Compensation & Retirement Funds
- A8 Taxes
- B1 Impounding Reservoirs Operation
- B2 Impounding Reservoirs Maintenance
- C1 Filtration Operation
- C2 Filtration Maintenance
- E1 Pumping Operation
- E2 Pumping Maintenance
- F2 Distribution System, Operation and Maintenance
- OE Other Expense
- O1 Watershed Property

are issued for rereads. Generally these rereads are but a small percentage of the total number of missed readings on the original route reading.

The route book is sent to the biller who computes the quantity of water to be billed, notes errors, bills the charges, and proves her billing on a special summary card for each route. The proved summary card is sent to the control clerk. The bill is the usual post card utility bill, printed in two parts, the original and a second bill used as a duplicate. This is economical both as to postage and elimination of time required to stuff envelopes. However, past-due bills are sent in closed envelopes.

The billing operation includes the printing of the "duplicate" bill at the time of printing the original. This eliminates errors that might occur in preparing bills for consumers requesting duplicate bills, and the bills sent to consumers delinquent in their payment. This eliminates a large amount of time that would be required to prepare these bills separately.

Cash payments made to the cashiers are balanced to the total of stubs from the receipting machines. The stubs are removed from the machine by the supervisor. Payments received by mail are checked with the corresponding stubs. The stubs are sent to the ledger posters and the receipts are deposited with the finance department daily. The posting to the ledger sheets is made on a daily cash receipt basis from the bill stubs. This posting is checked with the cashier's cash report and stub total.

The route reports from the billers and the daily reports from the cashiers are summarized from the route control's which are consolidated into nine district controls and finally into a system control. At the end of the 20 day net payment period, the difference between the net and gross amounts is picked up from the ledger sheets and posted to the control. The use of vertical ledger sheets filed in off-set position makes it easy to list unpaid accounts. At the same time, the duplicates of unpaid bills are pulled from the file. At the end of a 30-day period the duplicate bill for unpaid accounts are mailed. Twenty (20) days later a "final notice" is mailed and if no payment is made within 10 days a turn-off order is issued.

General Accounting

The necessary auxiliaries to general accounting such as preparing payrolls and record of materials purchased and used is a function of the subsection on general accounting. Bi-weekly payrolls are prepared from approved time slips for hourly rated men and from the established schedule for salaried men. Earnings only are entered on the payroll sheet which are then sent to the City Finance Department for necessary deductions, and the preparation of checks. Employees employment status, salary, and absence records are maintained by this subsection.

The procedure for purchase of supplies is as follows:

1. A request from a section head is approved by the Superintendent & Chief Engineer.
2. A requisition approved by the Superintendent and Chief Engineer, the Mayor and the Director of Public Service is forwarded to the City Purchasing Department.
3. Before the Purchasing Department issues the order for the purchase, it is approved by the City Finance Director, who encumbers the proper fund.
4. When the order is issued, a copy is sent to the water department to form the basis for a departmental encumbrance charge.
5. When material is received, the City Purchasing Department is notified.
6. Approval of invoices and their certification to the Finance Department is a function of the City Purchasing Department.
7. A copy of the paid invoice and city voucher is sent to the water department for record and accounting purposes.

Budget Control

Control of the Budget is a year-long problem for the utility manager. Control of the Budget involves a month by month knowledge of the *cash* status of the various functions involved. The status of financial condition of the utility at the end of each month should be available to the manager not later than the 15th of the following month. Many budget controls by fiscal-minded personnel are not only considerably behind this schedule, but is so broken up that it does not furnish the manager with the necessary up-to-date information for his control of the economical operation of the system. The fiscal-minded personnel consider funds only on a yearly basis, making necessary closing-out and adjustment charges at the end of the year.

Therefore, it is very essential that a budget control for the system on a cash basis be maintained by the utility personnel. The breakdown of this utility control will depend upon the system make-up, and the desire of the manager for that information which he considers necessary for his control of economic operation. Of course, if at all possible this operational breakdown of the utility should be such that the various items can be reconciled with those of the Finance budget.

In like manner, encumbrances against the various items must be followed closely. If not, the manager may find that work will be delayed due to the fact that the given item has the "No Funds" sign which may require transfer of funds before the given materials and equipment can be purchased or funds assigned.

For adequate budget control (which is really a system of cost accounting) inventories are essential. Purchases of materials which normally would be charged directly to an account should first pass through an inventory account if such purchase is for more than a 3 or 4 months demand, and are of considerable value. Cited are such items as coal, pipe, and fittings, service materials, curb meter settings, meters and meter parts. Likewise, an encumbrance item is necessary on the Income item of Reimbursement of Recoverable Expense to cover the backlog of services or meters paid for but not installed. For instance, water mains and services are to be installed in a real estate development or in annexed territory. Money may be received in the fall of the year but the installations are not made until in the spring of the following year. Without an encumbrance account the recoverable operation item will show a large income/expense ratio at first, with a corresponding low ratio later. This encumbrance is as essential as the encumbrance item for unfilled orders and contracts on the expenditure side of the budget. Good budgeting, good accounting, good spending, all are essential items of good management.

Water Works Billing Department

by FRANK G. INCE,
Retiring Treasurer, Des Moines Water Works, Des Moines, Iowa

OPERATORS can reach the printing calculator by merely pivoting in their chairs.

■ THE ADDITION OF one small piece of office equipment has significantly increased work produced by four clerks who send out all the Des Moines water and sewage bills.

Many Diverse Calculations

As many figures as possible are reduced to chart form, and often bills for residential customers, billed quarterly, can be taken right off them. But, there are many deviations from the standard that could not be put on a chart without making it so large that it would be unwieldy. Large commercial users or apartment houses frequently have bills that go beyond the charts. Their sewage charges on the same bill, are often too complex. And many out-of-the-ordinary residential bills can't be charted—like new bills, cutoffs, stopped meters, and the like.

This means that clerks are often called upon for many calculations they must work out themselves. Until recently, they either did these in longhand or used a machine on the desk of the chief clerk. The objection to this was that they had to leave their own desks and, of course, the machine wasn't always available to them. The Company couldn't very well purchase a calculator for each clerk, yet the lack of efficiency inherent in the situation had to be corrected.

The Solution

Mrs. Yount the Chief Clerk suggested the solution, which came with the installation of a printing calculator on a swivel stand between the girls. All four can use it simply by turning slightly in their chairs.

Because of its design features, the calculator has improved the work flow all along the line. Operated with adding machine simplicity, it performs the full range of calculations—addition, substraction, multiplication and division—printing both the component figures of a problem and the full answers on its tape. Proof of accuracy is established merely by glancing at the tape, to be sure the proper figures were entered into the machine. With nonprinting type calculators it is necessary to repeat each problem twice to establish accuracy.

A clerk completes a calculation, then tears off the tape to use in making up the bill. She doesn't have to carry figures in her head.

Billing Methods

The calculator is used on fully half of the large monthly bills, and many of the quarterlies. Among the calculations performed are water bills for the big consumers. Our four rates are based on volumes per day, so that a business establishment or apartment house that uses a lot of water will accumulate totals in each rate. All bills are figured on the exact number of days between meter readings, therefore the clerk figures the total in each rate.

Another calculation involves sewage charges for large users except when there is a sewage contract, which is the case with some commercial establishments. On invoices falling into the first two rate levels, the sewage charges is 35 cents per 1000 cubic feet of water consumed.

On large users who accumulate charges in all four rates, the machine is used to add water consumption under the last two rates, multiply it by 35 cents, and add to it 20 per cent of the water bill in the first two rates. This gives the clerk the total sewage charge for the month.

When a bill exceeds $50, as most of the commercials do, the calculator is used to figure the state tax. On residential bills, it is used for several types that fall outside the figures on the charts. For example, when a meter stops due to mechanical failure the clerk calculates the customer's average daily consumption a year ago, by dividing total consumption between readings by the number of days between the recent readings to get the new bill.

The machine is also used to figure first bills and final bills, because they are often for periods of time not charted. The same applies to back bills, when we haven't been able to get in to read the meter for some time. The charts only go up to 45 days, and bills for periods longer than that are figured on the calculator. So are overpayments, which must be substracted from the current amount due to get the corrected bill.

The girls also use this calculator to balance their abstract sheets, which accumlate everything they've billed during the day. It is often used to add up cash tickets taken in at the front counter. In this case, of course, the printed tape is saved and becomes part of the record.

Financing Small Water Utilities in California*

by ALLEN D. HARPER

Vice-Pres.,Securities Dept., Pacific Mutual Life Insurance Co., Los Angeles, Calif.

California is the home of the most rapidly growing, privately owned water utilities in the country. There are, in this state, probably a larger number of strong, independent, relatively well financed water utilities than in any other comparable area in the country. At least eight privately owned utilities serve more than 25,000 customers—which is equivalent to furnishing service to a city of 75,000 population. These utilities generally have property investments of at least $7,000,000 with gross revenues of $1,200,000. This is no longer only small business. The following observations however are directed not only to this relatively financially sophisticated group but also to that much larger body made up of small utilities. Their financial problems essentially have developed as a result of exceptionally fast growth, inflation, and increasingly "tight" money. These three major factors have, in fact, been affecting all business and especially all public utilities.

An example of extreme expansion is one of the water utilities in Southern California which has expanded services from roughly 2,000 in 1947 to 36,000 at present and investment from $500,000 to $12,500,000. Its management has been faced with serious problems concerned with new capital, new and adequate sources of water supply, personnel, development of accounting systems, public relations, and maintenance and development of improved engineering standards.

Growth of utilities in outlying areas has been particularly great, for almost all California cities have spilled out into the suburbs and rural areas. Most of these areas are served by privately owned utilities, by mutuals, and, in some instances, by county water districts. Since the growth is not ended, this process will continue to affect many. It is almost impossible to list adequately all individual problems. It can be pointed out, however, that the effect of growth is to emphasize the adequacy of long-range planning. Planning means adoption of higher standards of engineering, the development of adequate sources of supply, and, probably, greater interconnection not only between the various parts of one water system but also between various adjacent properties.

Higher costs affect all business and, particulary, public utilities which necessarily must spend large amounts of money to meet expanding requirements or merely to continue replacement of worn out installations. Average capital outlay per customer continues to inch slowly upward. It is recognized clearly that many utilities have been unable to forsee accurately the extent of the expansion which has occurred in their area. Conservatism in estimating growth has probably led many to design inadequate systems. If this results in a subequent replacement of small lines to provide additional capacity, clearly there is waste. Some is unavoidable, of course, but careful engineering procedures should be developed.

Sources of Capital

Since 1946, there has been, generally, a steady movement toward a higher cost of money. Although money is still relatively cheap in this country—even when compared to earlier levels of interest rates such as existed here in the 1920's—to be concerned with past, extremely cheap money will accomplish nothing for those who need money under today's conditions at current interest rates. The problem which many have is actually less one of interest rates and more one of finding an adequate source of long-term capital. It is basically where to seek capital and what methods should be used to attract it. It should be understood that some of the following suggested solutions will not be appropriate in all circumstances.

Sources of capital available to any privately owned water utility are common equity, preferred stock, donations, construction advances, bank loans, and long-term debt.

Common equity in the smallest company usually represents the capital of an individual owner and that contributed by his family or friends. Retained earnings are relatively unimportant as a source of capital because company growth is usually too fast to permit accumulation of significant sums by this route. New common stock is required and, generally, must be sold to local customers, friends, and individuals conservant with the company and its service area.

Preferred stock is also frequently sold by small companies to their customers. This source of capital is generally quite limited but very important to individual companies. Clearly, sales of preferred stock to customers depend to a large extent on the local reputation and standing of the water utility's management. Only a relatively few of the larger utilities in California have been able to establish a truly marketable preferred stock in the industry.

Donations arise largely from expansion operations which are in themselves entirely or partially uneconomical and for which customers are required to provide all or part of the capital needed. This cannot normally be regarded as a source of long-term capital.

Construction advances are somewhat comparable to donations except that construction advances generally are required from subdividers in connection with development of properties which will be very desirable from

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an economic standpoint when all or substantially all of the anticipated customers are connected to the utility's lines. Some utilities have used construction advances very extensively as a means of financing their rapid expansion. In some instances this has been seriously overdone. Certainly, under prior methods of repayment of the construction advances, those making extensive use of the 10-year, 35 per cent of gross revenue repayment method were dedicating a large percentage of future gross revenue to debt service. Fortunately, this method is now probably completely abandoned.

The present method of repayment of such construction advances from 22 per cent of gross over a 20-year period is also probably too severe a requirement on the water utility. Under present commission rules the monies received under construction advances are not considered as part of the rate base. Therefore, a water utility is theoretically not given any earnings from these properties except the amount equal to depreciation on them. It would appear that the 22 per cent of gross revenue repayment may require the company to pay back all its cash earnings derived from the particular properties constructed out of funds received under construction advances. A water utility, then, which has built a substantial portion of its properties with funds of this type would find itself with a severe cash shortage because earnings could easily fall short of supporting normal operations, debt service, actual replacement requirements, and return of capital to the subdividers. This device of requiring subdivider to provide, in effect, substantially all the money for expansion should be reviewed most carefully in relation to total capital obligations of the particular industry.

There have been a number of instances where companies exchanged the 3 per cent preferred stock at par for these construction advances. This, apparently, has been very desirable from the standpoint of the privately owned water company for, after the construction advances have been traded for preferred stock, the properties become part of the rate basis. Thereafter, the preferred stock dividends on the new stock actually are less of a cash drain than was the refund of 22 per cent of the gross revenue. There will be little gain to the water utility unless the entire amount being so exchanged for preferred stock can be added to the rate base. It is strongly urgent that any privately owned water utility which has been extending extensively its construction by means of construction advances avoid building up too heavy a construction advance liability.

Bank loans, basically, are a temporary means of financing any construction program. No public utility can or should build up extensive bank loans without having first determined the manner in which they can and will refund these from a permanent source of capital.

Long-Term Debt

Many utilities place a great deal of emphasis on securing the lowest possible interest rate in developing their long-term borrowing. At times this may be a decided mistake, as the greater emphasis should be placed on securing the most genuinely advantageous general business terms. Creation of a long-term debt involves the careful development of a contractual relationship which must be worked out in sufficient detail to be satisfactory to both the borrower and lender.

Inexperienced borrowers sometimes misunderstand various loan terms, perhaps because they do not realize that the complexity of the agreement is necessary to provide sufficient flexibility to permit the utility to conduct a normal business over many years.

It is not practical to attempt to establish specific ratios indicating for each special circumstance how much long-term debt may be safely incurred. It is felt that the establishment of such ratios frequently oversimplifies the problem. Clearly well established utilities serving desirable areas, and with proved ability to raise additional equity when, as, and if needed, can prudently borrow larger amounts relatively than small utilities whose management is less experienced in financing matters and whose service area is comparatively confined. Management should realize that creation of a debt imposes upon it a fixed charge not only for interest but ultimately for repayment of the amounts borrowed.

Excessive debt certainly lessens the general attractiveness of a utility's equity and makes it more difficult to interest additional investors in a company's preferred or common stock.

One of the most important considerations when selecting a program for permanent financing is the question of what effect this particular financing will have on the ability to raise additional funds. It is very poor policy to exhaust long-term credit in the hope that either additional funds will not be needed for many years or that when such additional funds are needed there will be no trouble in raising all that is required through the sale of equity securities. Under some circumstances equity capital is very difficult to find. Therefore, it seems wise to always keep some margin of borrowing capacity available for emergency use.

Interest Rates

Interest rates concern all business which must raise additional capital. Considering the large amount of capital needed by water and other utilities, this constitutes an even greater concern. In recent years, the cost of money has increased rather steadily. Most, at times, will forget that money even today is not historically high priced. Although interest rates are materially higher than those paid in the last 25 years, they are still generally low compared to those paid in the 1920's. Rates are also low in this country compared to almost any place else in the world. The change in rates should be viewed as a restoration of more normal interest rates. This increase has occurred as a result of extremely active business conditions which required heavy capital expenditures and borrowing by industry and individuals over the entire postwar period. The demand for capital in those years has been so heavy that the cost of money has been forced up to more normal levels after having been abnormally low during the prolonged period of depression and war ending in 1945.

California Regulations

The increasing cost of money has undoubtedly caused many to realize the necessity for rate adjustments. Certainly if utilities are to prosper in California, they must be permitted to earn a sufficiently high rate of return to enable them to attract capital on a fair basis. The belief, current in investment circles around the country, that regulations in California have

been too strict is shared by the author.

Many utilities in other areas have been permitted to earn materially higher rates of return than do those in California. The area is certainly a growing one and the growth does not seem to be slackening. Unless investors believe that they will receive satisfactory earnings over a long period of time it is quite probable that they will tend to invest in other areas —not only from a geographical standpoint but also from an industry standpoint. Managers and owners of privately run water utilities should take every possible step to make sure that investors are well treated. This means that there is an obligation to the owners to request rates sufficiently high to provide an adequate rate of return. If the return on capital invested in California utilities proves to be inadequate, relative to other states, it is going to be increasingly difficult to attract capital to the water industry. This ultimately would mean a deterioration of credit and of service to consumers. Earnings must be sufficient not only to attract capital but also to be fair to present investors.

There is no single continuing fair rate of return. The Public Utilities Commission in California certainly recognizes this fact and has generally been somewhat more lenient toward small utilities. This approach for the smaller utility is generally fair as the risks to the investor in placing his funds in smaller water companies are undoubtedly greater than in making investments in major, well established utilities.

Methods of Financing Water Utilities

in Michigan

by LOUIS E. AYRES

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This article discusses the sources of capital and of income, other than commodity rates, required to finance a water utility. This is a subject of particular interest under present-day pressures of suburban development and the handicaps of legal limitations.

The capital required by privately owned water utilities is limited to borrowed money and is obtained through the sale of common and preferred stocks, debentures, and mortgage bonds, or from bank or other short-term loans. Utilities under state water commission control may not plow earnings back into the capital structure. The income of a privately owned utility is limited to approved commodity rates and fire-protection charges.

Publicly owned water utilities, although much of their capital is derived from borrowed money through the sale of general-obligation, special-assessment, and revenue bonds, may secure additional funds from: taxes; surplus, or the profits of past operations; contributed funds, private or governmental; and various other devices such as the front-foot assessment, or capital, connection, and benefit charges.

Background History

In Michigan's early days water supplies were provided and financed by the family. Water was obtained from wells—individual house wells or community wells—or from surface streams and lakes. The early settlers of Detroit, for example, obtained their water supply mostly from the Detroit River. It was supplied from a pump on a wharf and carried:

> . . . in casks and barrels hauled in carts, and in buckets slung at either end of wooden yokes; . . . and the ordinances of the trustees compelled each citizen to keep on his premises a cask containing a certain amount of water and so arranged with poles for handles that it could be brought into immediate use *in case of fire*[1].

This is an example of the fire-protection service of a century and a quarter ago.

With the growth of communities to more than a few hundred families the need was soon felt for a system of distribution pipes to supply water for domestic use and fire protection.

Detroit

On Mar. 30, 1827, a private company was given the exclusive right of supplying Detroit with water. "At that time the city contained about 1,500 inhabitants. For the use of water families were charged $10 per annum[1]." Although the company "continued to expand the works in the face of increasing pecuniary loss, it failed to furnish a constant supply . . . of pure, clean, and wholesome water." Its charter was, therefore, forfeited and its property was purchased by the city on Jun. 4, 1836, for $20,000.

With the purchase of the company's property Detroit was faced with an expenditure of more than $180,000 for new facilities. In spite of all efforts to improve conditions, "the Common Council was besieged with petitions for relief and for reduction of rates and found itself in nearly the same situation that its predecessor, the Old Hydraulic Company, had been in only 15 years previously." This condition appears to have been caused by the rapid increase in population, inadequate rates, lack of experience in water utility practice, and Common Council management: "Many discussions and debates were held as to the policy to be pursued . . . Many were in favor of a sale to a private company, . . . others were strongly opposed to such a course. Finally, in February 1852, the council passed an ordinance by which the control and management of the water works were vested in a board of trustees, consisting of five members, and on May 16, 1853, the Board of Water Commissioners was organized." At this time the population of the city was more than 35,000.

This new Board of Water Commissioners, which was created by an act of the Michigan legislature, had broad powers. Pertinent to this article, it had the power to borrow money and to issue bonds, pledging the faith and credit of Detroit for the payment of their principal and interest. The board also had the power to assess a water rate which would "become a continuing lien" upon any "house or other building and upon the lot or lots upon which such house or other building is situated." In addition, if any sum was needed "over and above this revenue . . . to meet the payment of interest or principal of bonds issued . . . it shall be the duty of the Common Council to raise said amount by a special tax in the same manner as general taxes."

From 1876 through 1919, inclusive, more than $3,000,000 was collected by special taxes and paid to the board. In the early days receipts from taxes sometimes amounted to as much as 25 per cent of gross receipts from water assessments. Toward the end of the period money received from taxes dropped to as little as 3½ per cent of gross receipts from rates.

Revenue that now comes from meter sales at first was collected in Detroit by means of a flat-rate assessments, established in the bylaws of the Board of Water Commissioners Feb. 14, 1854. The first meters appeared in 1878. By 1890, 10 per cent of water services were metered, by 1924, 50 per cent, and by 1930 almost all sales were metered.

Types of Charges

Front-foot assessments and charges

The front-foot benefit charge is an annual charge and a contribution to income. It should be distinguished from the commonly used front-foot assessment which is levied on property at the time a main is laid and is intended to cover, in part, the capital cost of the main extension. Front-foot assesments are common but are generally inadequate to cover the cost of the mains laid.

In a report to Detroit for the year

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ending Dec. 31, 1869[2] it is stated that: "The legislature of this state, at its last session, passed an act making it the duty of this board to assess an *annual tax of 3 cents* per lineal foot of the frontage of lots in front of which wate pipes are laid and which do not pay water rates." This tax, first assessed for the year 1870, amounted in that year to $6,446.40, about 4.65 per cent of total receipts from water rates. "The assessments were made annually, but no proceedings were had to enforce collection by sale of delinquent premises," until the beginning of the year 1876: "Upon suit brought by parties interested the Supreme Court of the state, at its last June [1876] term, declared the act in question invalid. All amounts collected under the act were repaid[3]."

It is interesting to note that in 1918, 42 years after the Michigan act, assessing an annual tax on lot frontage of nonusers was declared invalid. Maryland passed the enabling statute of the Washington Suburban Sanitary District, which provided that: "debt service on district bonds for capital cost be met by a low tax on all property in the district, plus a front-foot benefit charge on properties abutting water and sewer lines[4]." This benefit charge has now been collected for 40 years and in 1955 it accounted for about 31 per cent of the total income of the district.

Apparently an annual front-foot benefit charge is not only unconstitutional in Michigan but: "Legal authority is wanting in many jurisdictions[4]." Courts find that it violates a basic rule of taxation which requires uniformity of application of benefits.

Capital Charges

Capital charges are collected either as a lump sum to aid in plant expansion or as an annual addition to rates, equivalent to an extra demand or service charge.

Connection Charges

Connection charges are made to reimburse the system for the cost of services and of meters installed.

Customer-benefit charges

A customer-benefit charge permits new customers to buy into an existing water system. Such benefit charges, for both water and sewage service, were defined and adopted by an ordinance of the Common Council of the city of Ann Arbor, Mich., Jan. 16, 1956:

WHEREAS, there are certain properties in the city of Ann Arbor which have not been developed to the extent of being connected with the water and . . . sewer systems owned and operated by the city, and

WHEREAS, a benefit charge has accrued from said properties by reason of the construction and maintenance [of these systems] which afford and make available to such properties water and . . . sewer service since the inception of these services by the city, and

WHEREAS, such properties have not contributed any reasonable or appreciable amount toward the cost of construction of the existing [systems], and by reason thereof a benefit charge against such property should be made before such property is permitted to connect to the water and . . . sewer systems of the city to cover the property's fair share of the cost of such existing services.

Now, therefore, be it resolved, that a benefit charge shall be due and payable at the time of the installation of the water meter for . . . properties . . . not heretofore connected to the water and sewer systems of the city.

The schedule of benefit charges adopted by this ordinance varies from $75 for a single-family residence, $120 for two-family residences, $200 for four-family residences and up to $2,000 for 100-family residences, plus $20 for each family in excess of 100. There is also a meter schedule covering industrial, commercial, and miscellaneous, buildings with ranges from $75 for a ¾-in. meter to $6,800 for a 6-in. meter. A later amendment provided that those properties that were annexed to or a part of the city at the time of passage of the ordinance would be granted a 5 per cent discount per year for every year they were part of or annexed to the city prior to 1955. This discount may not exceed 50 per cent.

It seems to the author that such a so-called lump-sum benefit charge, which requires a later user to purchase his proper share in a plant that is operating and paid for by earlier users, offers a partial alternative to the Washington Suburban Sanitary District's annual front-foot benefit charge. This charge also is intended to collect in advance a proper share of the investment, to be credited to the later user when he subscribes to the water system. It is not practical, however, to make the lump-sum charge nearly as effective as the annual charge. The Ann Arbor lump-sum charge of $75 per single-family dwelling may be compared with the annual charge in Maryland on a 60-ft lot of $12 per year for 40 years, the life of the water district's bonds.

Fire-Protection charges

Years ago, it was a generally accepted theory that the income required to support a water utility should be derived from two sources: sale of commodity and payments for services. The commodity was purchased by the individual customer and paid for through water rates; the services were an obligation of the community as a whole and were paid for through general taxes.

One service in particular that has been accepted since the first days of water utilities is fire protection. In fact, in many instances, it was the prime function of the utility. It was the one public service that appeared to be susceptible of evaluation in dollars and yet it has been the subject of controversy for 50 years. Other services to the community, accepted as real and important yet not subject to precise evaluation, are those related to public health, sanitation, and the general well-being of the public. In recent years payments for fire protection have lapsed largely, except where maintained by state regulatory commissions. Although all privately owned water utilities are under commission control, municipally owned utilities are usually free from such supervision.

Other Charges

Expediency in taxation brought about the abondonment of a charge for fire protection because it involved a payment to the water utility that had to be appropriated by the city budget, which is burdened by many other demands for funds. However, special assessments to provide distribution mains and extend mains, capital charges to enlarge plants, connection charges to help pay for meters and services, and benefit charges to permit new users to buy into existing systems are all essentially charges to property, but not to the same property covered by the general city tax. All of these devices are available for use by the publicly owned water utility.

Extreme bases for financing a water utility would be to make "use of general tax funds to finance . . . major structures," the "use of special assessments to finance . . . local structures," or the "use of water charges to finance operation and mainte-

nance[4]." However, the propriety of reducing water rates so that they cover only operation and maintenance charges under normal conditions may also be doubted. To do so might reduce rates unduly and lead to waste. The objectives in rapidly growing areas are to: sucure the revenue necessary to finance water-service additions without placing too much extra financial burden on existing users and to finance service to new developments without resorting to excessive rates.

Legislation

Much legislation has been passed in Michigan in the last 30 years in an effort to aid in the financing of water-supply facilities in rapidly growing areas. In general, the purpose of the legislation has been: "to provide the necessary powers to larger governmental units, such as metropolitan districts, counties, and authorities to own and operate the required facilities and to finance the costs with the aid of both taxes and rates[5]."

The first act to create a metropolitan district was Act 312 in 1929:

> This act authorized the formation of a combination of two or more cities, villages, or townships to own and operate a water system, with only a limited power to tax in a special assessment district but with authority to sell mortgage and (later) revenue bonds. This metropolitan district idea was promulgated by the city of Detroit, with the expectation that an agreement could be reached on the organization of a water district to include Detroit and the surrounding areas. The plan never materialized[6].

The Revenue Bond Act of 1933 was the next important step in the financing of water utilities and under its provision many projects have been financed. It has served well in the past in connection with extensions and improvements to existing municipal plants. It is, however, inadequate to finance improvements for undeveloped areas if there are not sufficient customers at the beginning of a project to provide the necessary revenue without prohibitive water rates. One reason for this is that in financing with revenue bonds it is necessary to provide enough revenue to pay all operation and maintenance expenses plus 150 per cent of the debt service.

In 1939 the so-called County Plan was authorized by Act 342:

> . . . to fill the gap in the Detroit area left by the previous failure to form a metropolitan district. Under this plan the Board of Supervisors can authorize the formation of a water district within the county and finance the same by the sale of general-obligation or revenue bonds, and may tax the property in all the cities, villages, or townships served, and charge rates to the users of water. Under this law the Wayne County Road Commission developed a system of water mains through which the western portion of Wayne County is supplied with Detroit city water[5].

In 1952 Act 196 authorized:

> . . . the formation of water authorities by the incorporation of any two or more cities, villages, or townships, with power to own and operate a water system, sell revenue bonds, and contract with its constituents units for sale of its product. These bonds were made good by contracts with each city, village, or township which were severally authorized to raise by taxes and by rates the sums necessary to meet their respective obligations[5].

The cities of Berkeley, Birmingham, Clawson, Huntington Woods, Pleasant Ridge, and the township of Southfield were thus: "organized into an authority to purchase a water supply from Detroit and distribute it through master meters to the boundaries of the several communities[5]." This authority now includes the cities of Southfield and Lathrup and the village of Westwood.

In spite of the legislation of the last 30 years, and particularly of the last 5 years, the financing of water supplies in rapidly growing and extensive suburban areas presents problems for engineers, attorneys, and financial advisers. Additional sources of revenue, other than from water rates, have been sought. For example, in 1955 Act 233 authorized the use of state tax money and: "any other funds which may be validly used." And Act 4, 1957, authorizing financing by general-obligation bonds and stated that a: "tax for the purpose of paying the bonded indebtedness shall be unlimited as to rate or amount."

Difficulties in financing will continue so long as dependence is placed on the use of general taxes collected from an entire township or other political subdivision to supplement the income from rates collected from only a portion of the area involved. Rates are paid by users; taxes may be collected largely from nonusers of the service. Equity requires that both the users and the nonusers—or, users of the future—support the project. Although front-foot assessments and lump-sum benefit charges supplement rates no better device has been adopted than the annual front-foot benefit charge of the Washington Suburban Sanitary District, previously described.

Southeastern Oakland Authority

The Southeastern Oakland County (Mich.) Water Authority presents unique and outstanding examples of both water-distribution methods and the allocation of costs to customers. Water purchased by the authority is limited to a rate of demand not to exceed the average rate of maximum-day use and it is delivered to its constituent units at the demand rates required to meet their respective maximum hourly use. All water received and sold is measured through recording meters. The records of the authority, therefore, provide unusually complete data on hourly rates of water use, storage requirements, and related factors of importance in the intelligent design and operation of water systems.

This authority is also unique in its plan for distributing costs. In the original contract each unit purchased an estimated maximum daily demand for the year 1970 and each agreed to pay as a demand charge its proportionate share of 50 per cent of the total fixed charges. The balance of the fixed charges, plus operating costs, are included in a uniform water rate. Also, as time goes on, each unit will have the right to buy additional water or sell unneeded water at the originally established purchase price, corrected for compound interest to the date of purchase or sale.

The Southeastern Oakland County Authority will have increased its estimated water demand in 10 years (1950-60) to the growth anticipated for 20 years (1950-70). The contract has provided for this increase. The arrangement is generally accepted as successful and equitable. It affords an alternative method for the finacing and cost allocation of regional water supplies elsewhere.

1. *History of the Detroit Water Works.* Board of Water Comrs., Detroit, Mich (1853).
2. Annual Report. Board of Water Comrs., Detroit, Mich. (1870).
3. Annual Report. Board of Water Comrs., Detroit, Mich. (1876), p. 12.
4. Committee Report. Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works. *Ohio State Law J.*, **12**:149 (1951).
5. Ayres, L. E. Financing Water and Sewage Works. *Proc. 63rd Ann. Public Works Congress* (1957), p. 196.

Water Works Management

Illinois Section AWWA Short School

Labor Relations

One session of the school was a panel discussion, moderated by Edward E. Alt, of the Chicago Bridge and Iron Co., on the subject of "The Psychology and Philosophy of Labor Negotiations". Each panel member had 15 minutes to present his views and thereafter the session evolved into a question and answer period. Among the topics and ideas presented were the objectives of labor, perception and motivation as seen from different sides of the bargaining table.

Motivation from labor's point of view include maximum income, job security, good working conditions, security against old age, security against illness, security against arbitrary or discriminatory treatment, union security, and recognition as union leaders.

From management's point of view, motivation includes profit (maximum), service to customers, efficiency of operations, management's authority (not prerogatives) and flexibility, morale of employees, loyalty of employees, permanence and security of company prestige and status of management.

According to Phillip L. Garman, Professor of Labor and Industrial Relations, at the University of Illinois, who presented these comments, some of these goals are in conflict and some are consistent. Most of the conflicts revolve around how to divide the pie and management's so called prerogatives. There are no conflicts around efficiency or loyalty. As to the answer: Management should try to understand union goals and objectives and should try to get the unions to understand management's goals and objectives.

Public Information

■ PUBLIC INFORMATION—A MEANS TO WATER WORKS ADVANCEMENT, by Robert S. Millar, Manager, Board of Water Commissioners, Denver, Colo.

The breadth and depth of this subject is obviously great. It can not be covered completely in a short space of time, but as the subject is developed may we be ever mindful of the field within which we work. Water works advancement is our field. Not my water works or your water works; not Illinois water works, but *all* water works.

Every city, town and village is populated with individuals who sound off at one time or another telling you, the neighbors, their friends or the editor just how your business should be run. Are these people responsible for this abundance of knowledge, or misinformation, they have of our operations or are we to blame for having this condition so common as a part of our community life? If we are to blame, what should we do about it, what can we do about it? The answer: Public Information.

The truth and nothing but the truth is essential for any public information. Anything that is not truthful, through and through, should not be considered for public information. Untruths cannot be tolerated. The whole truth, however, in many instances would be not only wearisome and boring but could easily lead to misinterpretation, misunderstanding or even misleading and confusing the public.

Facts and Timing

Essential facts must be brought to the attention of the public at the proper time. It is not easy to release bad news at any time, but, facing up to the inevitable, and announcing what may prove to be bad news at some future date, eases the blow considerably when that day arrives and the bad news must be told.

Timing is of the essence. Here is where judgment is required. Here is where "Public Information—A Means to Water Works Advancement" strikes each one of us. Timing is not the only element which is governed by judgment. The amount of details, explained in great detail, also requires judgment.

Just about every water works operator knows the responsibility which

is his. Protection of the health against disease of epidemic proportions and protection of property against fire which could be a conflagration are two responsibilities which cannot be treated lightly. We must realize the job we have to do. Humility, someone has said, "is honest appraisal of one's self."

The first and, I believe, most important question we must ask ourselves is "Am I worthy of this trust?" We should work conscientiously to improve ourselves and those with whom we are associated. By attracting strong young people to our industry, then training them to be leaders we will accomplish that which our industry needs. No matter how we try, how clever we may believe we are, we cannot gracefully promote ourselves. We may, however, let the press, radio and TV people know about the accomplishments of our associates.

What does the public want to know about the water utilities? The public consists of such a heterogeneous mixture of people who are interested in so many different fields of activity that it can be truly said they want to know everything about our operations, *everything*! Have we tried to satisfy this broad demand? If we were to keep a record of all requests made, I believe we would find that a large number of inquiries relate to the cost of our service. To put it bluntly, "Why is my bill so high?"

The American Water Works Association has published good material on this subject. One of our big jobs is to let people know how cheap water service is. Many people never raise any questions about water service until something goes wrong. We have been providing such good service that people just take continuous good water service for granted. It is part of our job to determine what different segments of the public want to know—then tell the story in such a way that people will become more and more conscious of the low price paid for water service and more appreciative of the good service rendered.

How can the public be informed? The answer to that is really quite academic. The question which should be before us every day of every week of the year should be "What have I done, specifically what, to inform people of our accomplishments, our work, our problems?"

Check List

Here is a check list of how to handle information the public should have.

(1) News items are not the only material good newspaper men appreciate.

(2) The editorial writers are mighty grateful when a thoughtful water utility man gives them an idea or two to develop editorially.

(3) Many papers are looking for good subject matter for a special feature article. The water story has been used many times; sometimes in serial form running for several days.

(4) Radio news items, panel discussions and question and answer sessions attract a lot of attention, especially if advance notice can be given that the program is scheduled for a specific time on some station. TV has afforded many water utility men an opportunity to tell their story in a most interesting manner. Charts, diagrams and pictures may be used to good advantage on TV.

(5) Civic clubs are very happy to have you as the speaker—IF—you have something interesting to tell them. Church groups frequently have programs in which you could participate.

(6) Larger utilities have found moving pictures an excellent medium of expression. Amateur photographers have put together some creditable movies showing water utility operating and construction scenes. Some have written a commentary to be read as the movie is shown, some have sound track on the film. Some very fine colored movies with sound track and appropriate musical background have been made for larger utilities.

(7) Another medium is the brochure, sent as a separate mailing or with bills.

(8) Let us not forget that annual report. There are so many ways of making your annual report a first class carrier of all sorts of information to the public.

(9) There are other ways of getting the message to the people. When we do a good job, and perform consistantly, it is not too difficult to set the wheels in motion for the most ancient of public information media —word of mouth. If every employee is a conscientious worker, he and she *and* their families, *and* their relatives, *and* their friends can be the best source from which good news will spread so easily, so gracefully and so completely. Until the immediate family of utility employees is well informed, we will have difficulty spreading the good word to the general public.

(10) For a final thought, consider the slogan that was so impressive a few years ago—it is better than ever today—SILENT SERVICE IS NOT ENOUGH.

Organization

■ EFFECTIVE MANAGEMENT THROUGH ORGANIZATION, by Wayne A. Lemburg, Instructor, Bureau of Business Management, University of Illinois.

Organization is a process of identifying and grouping work, of finding and delegating responsibility and authority, and of establishing relationships to enable people to work most effectively together.

The problems of organization involve people, the division of labor, the source of authority, and personnel relationships or teamwork. Delegation of both responsibility and authority is important to good organization.

To Revaluate Organization

There are four steps to be taken in any attempt to revaluate an existing organization:

1. Make a list of employees, titles and duties.
2. Group employees under supervisors
3. Group supervisors levels
4. Get employees to participate, ask them to list their jobs and what they do, daily, weekly, monthly.
   a. What do they do?
   b. Names or titles they get orders or instructions from?
   c. What suggestions or advice do they give—or receive?
   d. What reports do they prepare and who gets a copy?
   e. What reports do they receive and from whom?
   f. How do they use the information in reports received?
   g. Other facets or factors in the job?

Delegation

No one should try to do everything himself; an individual is only one man and can do only so much, to do more he must assign and delegate. The difficulties in delegation stem from (a) lack of faith in subordinates and (b) lack of communication and checks on delegation.

There is, of course, an obligation on the part of the delegatee to produce on assignment.

The three elements of delegation are:

1. Work or responsibilities involved.
2. What is authority that goes with delegation.
3. What is obligation or accountability of subordinate back to manager.

Among the problems of delegation are: the manager is not relieved of responsibility for the action of others; it is often hard for the manager to find the man to whom delegation should be made; and it is often hard for a manager to give up his pet preferences for ways of doing things, but all managers should remember not to try to run a one man show.

Eight steps to successful delegation:

1. Look again at subordinates.
2. Take the middle road—If you look over a man's shoulder, you smother his ingenuity; but if you don't look at all some difficulty may arise; proper guidance is the middle road.
3. Measure the job for the man.
4. Tell top management, too, about subordinates' potentials.
5. Tell your man where he stands; make him understand his responsibility.
6. Make the job worthwhile; make it challenging; give sub-ordinate a chance to grow.
7. Set standards high, but not out of reach.
8. Reward the man—with money, job satisfaction, a pat on the back.

How to ease your burden—Delegate these items:

1. Responsibilities hanging over from past operations.
2. Recurring routine details.
3. Routine decision making (this should be delegated by establishing written policies.)
4. Jobs that take big chunks of time.
5. Functions you are least qualified to handle.
6. Details you don't like—find some one who does.
7. Duties that tend to over-specialize you.

When you want to develop employees, delegate these items:

1. Tasks that add to job skills or mold attitudes.
2. Tasks that provide variety.
3. Tasks that contribute to job wholeness.
4. Jobs that provide challenge.
5. A sequence of jobs of increasing difficulty.

Management Questions

Here are 13 important management questions designed to help you appraise your own application of management principles. Ask yourself each question contemplatively and answer objectively. You can thus note specific areas for self-development.

1. Am I a general manager doing an overall management job? Or am I a technical specialist in one or two phases of my business?
2. Do I have specific goals for my organization for the next five years? For the next year? If so, what are those goals?
3. Do I have plans for action that will help me attain company and personal goals? If so, are they sufficiently clear and definite to provide guidance for me and my employees?
4. Are all recurring situations that require decisions in my business covered by clear policies? Are these policies in a form, preferably written, so that they are uniformly *understood* and *applied* by every key employee in the company?
5. Have I recently analyzed the functions and activities which must be performed to meet the goals of my organization?
6. Have the functions been grouped in accordance with good organization to eleminate gaps and duplications?
7. Have all functions been assigned to appropriate personnel? Are all activities being capably performed by me and by my employees? Does each one understood thoroughly his authority and responsibility?
8. Am I providing leadership through ideas in my organization?
9. Do I make decisions on the basis of all the facts? Do I unnecessarily duck making decisions or put them off?
10. Have standards of performance been set up for every element of my business affecting profits? Do I regularly check actual results against the standard?
11. Does my system of accounts and records indicate promptly when something is wrong? Does it help me to take remedial action *where* required, *when* required?
12. Am I systematically getting the benefit of the ideas that my employees have for improving our business? Do we operate effectively as a team in my organization, with interchange of ideas up, down, and across?
13. Do I have a systematic plan for management development—for myself and my key subordinates? Is the plan working?

Business Outlook—1959

■ THE BUSINESS AND ECONOMIC OUTLOOK FOR 1959, by Robert T. Hill, Asst., Prof. of Finance, University of Illinois.

The major determinants of the 1958 recession included these factors:

1. Post war expansion of production from 1947 to 1957.
2. Pent up demand for housing.
3. Shortage in autos and other consumer durables.
4. Post war period required rehabilitation in other parts of the world to the extent of $65 billion and now there are less and less exports.
5. Financial maladjustments, particularly with respect to the increase in private indebtedness.
6. Wage and price spiral and some inequities therein; particularly the increase in number of pensioners; and the decrease in purchasing power of the dollar from 1946 (119.6 per cent) to 1957 (82 percent) based on the 1947-49 dollar as 100 per cent.

In addition to these major determinants, there were a number of compounding and temporary factors:

1. Liquidation of inventories at high rates.
2. Decline in housing construction. This was partly due to tight money policy which has now been reversed.
3. Decrease in public works.
4. Policy of credit restraint.

As to the severity of the recession—Production was down from 147 per cent to 126 per cent of the 1947-49 average. Unemployment reached 7.7 per cent. The disposable income, however, decreased only slightly. Most seriously affected were producers of capital goods, producers of durable consumer goods, metals and minerals producers, and the railway transportation industry.

What's Ahead

The business indicators reversed in April 1958 and here are the factors of strength:

1. Federal Reserve Board Index of Production is on upgrade.
2. Housing starts have shown a moderate rise since the bottom was reached in April.
3. Major consumer durables are on the rise.
4. Employment has been on the upgrade since last May.
5. Personal income has been rising since May.
6. Retail sales are up.
7. Farm income was up in the 3rd quarter and reached a plateau.
8. Total bank credit is up.
9. Municipal bond borrowing has increased.
10. Prices in metals have strengthened.
11. Resiliency in European business.

At the same time, any consideration of what's ahead must consider these factors of weakness in the present situation:

1. Continued decline of plant and equipment expenditures.
2. Decline in new construction.
3. Continued liquidation of inventory.
4. Softness in automobile production and sales.
5. Wholesale prices have not dropped.
6. Consumer credit has not bottomed out.
7. Secondary market credit has remained high; the upward market trend is due to the belief that the recession bottomed out in April.

The business recovery looks sound and on the upgrade but the pace will slow down. The government will slow it down to slow down inflation.

Responsibility for Utility Relocation

by ROBERT P. HEYWOOD, Esq.
Town Attorney, Town of Colonie, N. Y.

The general subject of state responsibility for relocating municipal public services is one that requires an examination of the authorities with respect to municipalities in general. While the concern here is only with towns, a look at what the cases have said with relation to all municipalities is necessary for a proper understanding of the subject. It has been said that the state has an absolute control of the highways, including streets, even though the fee be in a municipality. Such powers of supervision and control may be exercised directly by the legislature or may be delegated by it to subordinate or local governmental agencies or such authorities as it may deem satisfactory. The state may permit the use of the highways and streets for any purpose not incompatible with the object for which they were established. The power to control highways and to provide for the proper adjustment of conflicting rights and interest therein is a police power. Legislation exercising it need not be uniform throughout the state.

The public easement in any highway includes the right to lay pipe or conduits beneath the surface for the benefit of the public. In 120 U. S. 64 which, incidentally, was not a case arising in New York State, it was said that the right to dig up and use the streets of a city for the purpose of laying water pipes is a franchise which the state may grant to persons or corporations upon such terms as it deems best for the public interest accompanied with such exclusive rights in the grantee as may be deemed best to promote the public health, comfort and safety.

Provisions of Law

With these general thoughts in mind, the statutory provisions of the Town Law of New York State with respect to the installation of municipal services within the rights of way of the state highways and, further, the Highway Law setting forth the powers and duties of the superintendent of public works will be examined. Generally speaking, Section 198 of the Town Law provides that after a water or sewer district has been established, the town board may cause pipes and necessary appurtenances thereto to be laid, relaid or repaired in or under the surface of any highway in the county in which such town is located or in an adjoining county for the purpose of transporting water to a water district in said town and shall cause such highway to be restored to its usual condition at the expense of the district. No water or sewer pipes shall be laid if such a highway be a state or county highway or a highway constructed pursuant to sections 194, 195 and article 6 of the Highway Law of New York State without the consent of the state superintendent of public works.

Section 3 of the Highway Law divides highways into certain classes:

1—"State Highways" are those constructed or improved at the sole expense of the state, including certain highways specified in other sections of the law.

2—"Controlled Access Highways" are those highways entirely or partly constructed, reconstructed or improved at a location where no public highway, theretofore, existed and to which the occupants of abutting property shall have no right of access either as pedestrians or otherwise.

Section 10, subdivision 24, of the Highway Law says that the superintendent of public works shall have power, whenever he deems it is necessary as a result of construction, reconstruction or maintenance of state highways, to provide for the removal, relocation, replacement and reconstruction of water mains, sewer pipes, and any other facilities that are owned by any municipality and are maintained for public use. The expense of such removal, relocation, replacement or reconstruction shall be a proper charge against funds available for the

"The public easement in any highway includes the right to lay pipe or conduits beneath the surface for the benefit of the public."

construction, reconstruction or maintenance of state highways, and such work may be performed by contract or by the use of department forces and equipment and of materials purchased therefor. However, if the superintendent of public works deems it to be in the interest of the public, he may contract with the municipality, upon such terms as he may deem advantageous to the state, to have such work performed (a) by the employment of the forces and the use of the equipment of such municipality and by the use of any material on hand or necessary to be purchased by such municipality, or (b) by such other method as such superintendent of public works shall approve, or (c) by a combination of the methods provided in this subdivision. Any such municipality is hereby authorized to enter into such contract for the purposes of this subdivision. Upon the completion and acceptance of the work such water mains, sewer pipes and other facilities shall be maintained by the municipality. As used in this subdivision, the term "municipality" shall include a public water authority.

Under Section 10, Subdivision *27* of the N. Y. State Highway Law, the superintendent shall have power, upon the request of a municipality, to perform for and at the expense of such municipality, any work of construction or reconstruction, including the removal and relocation of facilities, provided he deems it practicable to perform such work for the municipality in connection with the performance of any construction, reconstruction or improvement. Whenever the superintendent of public works shall approve such a request, he shall make an estimate of the cost of the work which he is requested by such municipality to perform, in accordance with plans and specifications submitted to him by the municipality. Such municipality shall thereupon deposit with the state comptroller a sum equal to such estimate and subject to the draft or requisition of the superintendent of public works. When the work authorized by this subdivision has been completed and the cost thereof shall have been paid by the state, the superintendent of public works shall render to the governing body of such municipality an itemized statement showing in full (a) the amount of money that has been deposited by such municipality with the state comptroller as hereinbefore provided, and (b) all disbursements made pursuant to this subdivision. Any surplus money shall be paid to such municipality on the warrant of the comptroller or vouchers therefor approved by the Superintendent of public works.

> *"In order to minimize future delays and expenditures necessitated by the moving of such utilities when a highway is improved . . . it is necessary . . . to control the location of such facilities."*

Legal Interpretation for Districts

In 1946, the Attorney General made response to the inquiries of the State Department of Audit and Control as to whether any work of construction or reconstruction under subdivision 24 could be performed in "districts" at the expense of the state. The Attorney General's opinion cited former confusion as to the relationship of a water or sewer district to a town. Much litigation had ensued, with the Court of Appeals in the case of Kenwell vs. Lee ruling that an improvement district was only a special administrative area. Before the enactment of subdivisions 24 and *27*, by common law, the holders of such facilities located in the public highways were bound to make such changes at their own charge as public convenience and security require. It must be presumed that the legislature, in the enactment of this statute, had knowledge that the public highways had underneath them water and sewer pipes and other facilities belonging to water and sewer districts. The emphasis is placed in the use of the expression *"maintained for public use."* The clear intent was to include as a proper charge against state funds the removal and relocation of publicly maintained facilities and to exclude non-publicly maintained facilities. In another Opinion, also in 1946, the Attorney General stated that subdivision 24 was limited, as to location of the work of the superintendent, to the *state highways*. The Attorney General went on to say that subdivision *27* to Section 10 is unlimited as respects the place of the work except that the work must be done in connection with the performance of any work of construction that the superintendent of public works may be doing pursuant to the Highway Law. The Attorney General at this time also ruled that the word "municipality" included both water and sewer districts and that the powers of the Board of Commissioners were the same as the powers of the town board operating the district.

Position of the D.P.W.

One step further, and to get to the crux of the further problem, examine the position taken by the N. Y. State D.P.W. through the office of the Chief Engineer with relation to the subject which they call initially, "Utilities Along Right of Way of Interstate Routes." On 9/25/56, the Chief Engineer's General letter #56-9, the ruling was set forth as follows: "After consideration it has been decided that except in special cases in which *our* needs must be served the installation of utilities along the right of way of the interstate system and other limited access express-way routes shall not be permitted. Exceptions from this general policy will be granted only by the Chief Engineer and on the recommendation of the district engineer."

On 5/22/57, Chief Engineer's General letter 57-28 on the same subject, the following language was used:

> *"Obviously there is a need for advanced planning on the part of the towns and need for complete cooperation with the Department of Public Works."*

"Since the issuance of Chief Engineer's General letter 56-9 on 9/25/56, the subject of utilities along the right of way of highway routes has received further study. During this same period, several pertinent suggestions have been received from the various district offices. The additional study and the suggestions received indicate that a revision and extension of the policy is desirable.

"In a statement by C. W. Enfield, General Counsel, Bureau of Public Roads, it is pointed out 'the bureau's study indicated that in approximately one third of the State's Highway Construction, progress is often seriously impeded by delay in utility adjustments; that in another third it is occasionally impeded, and in the remaining third delays seldom occur.' We have all experienced the delays referred to in Mr. Enfield's statement and in addition the experiences of several of our districts clearly indicate that drainage has been seriously impaired and pavements and shoulders extensively damaged, by the installation of utilities along these shoulders.

"Therefore, in order to minimize future delays and expenditures necessitated by the moving of such utilities when a highway is improved and to protect our drainage system, shoulders and pavements, it is necessary that the policy be revised and extended to control the location of such facilities.

"Beginning at once the installation of utilities within the right of way on our *non-controlled access State Highways* will be limited to those areas outside of the ditch line. Utilities will, in general, be installed as close to the outer limit of the right of way as possible. The fact that this may be physically difficult to do does not alter the situation.

"In those areas where it is anticipated that pavement widening will be done no permits will be given to install utilities inside of the *new* ditch line. If, in these cases, this new ditch line falls outside existing right of way, no utilities may be installed within existing right of way. The utility company, or owner, should be advised of our ultimate taking so that if he elects to obtain his own right of way, it will not conflict with the future highway widening.

"In cities and villages each case will have to be determined on its merit, keeping in mind the intent of the above policy. In general, and if practical and feasible, pole lines should be placed on the outer right of way line. Sewers, water lines, and underground ducts for cables should be placed back of the curb and properly separated. Sidewalk areas are particularly adapted for the use of these underground facilities since the digging up of these lines for repairs will do much less damage and cause less interference with traffic than if they are under the pavement.

"On State Highways, both rural and urban, our control must be positive and spelled out definitely and in such detail as is necessary to maintain this control. Care should be taken in the back-filling of any such trench in the right of way to *make sure* that the *intended drainage* both surface and subsurface is not interrupted or impaired.

"The instructions set forth in this General Letter are not intended to alter in any way those set forth in my General Letter 56-9 dated 9/25/56. This is intended to amplify and extend the instructions so as to cover our non-controlled access State Highways as well as our Interstate Routes and Expressways."

> *"Some form of legislation should be considered to give to the towns the right to lay pipe in the highway."*

Effect on Utilities

It should be noted that what started out to be a general policy with relation to limited access highways had now been extended to non-controlled access state highways, and in this last letter the department has taken into consideration the probability that the districts may have to obtain thir own right of way by a private easement. The effect of such a ruling is to place the burden of additional cost of securing private rights of way upon the districts. In many cases, the effect of this ruling would make the cost of installing sewer and water systems for improvement districts entirely prohibitive. The suggestion has been made that this interpretation of the Department of Public Works is too restrictive, expensive, unnecessary and deprives the communities of rights to which they are justly entitled. However, the sections of the Town Law involved used permissive language in that they state that the town board *"may"* exercise the power of causing pipes to be laid below the surface or in any public highway. As a matter of fact, the permissive language is further qualified by the fact that the consent of the state superintendent of public works is required where a state highway is involved. In the two subdivisions of the Highway Law which have been heretofore cited the final decision to expend state money for construction or reconstruction, removal or relocation in state highways is left to the discretion of the superintendent of public works where he deems it necessary. Even in subdivision *7*, we must note that the superintendent of public works must deem it practicable to peform the work for the municipality. Obviously there is a need for advanced planning on the part of the towns and need for complete cooperation with the department of public works in determining the routes of proposed expansion or reconstruction of state highways in relation to existing municipal installations and planned extensions of various districts.

Proposed Legislation

As an additional suggestion, some form of legislation should be considered to give to the towns the right to lay pipe in the highway, a right to which they have been traditionally entitled. Also, it should be provided by legislation that the state pay for relocation and reconstruction of public service facilities in the case of highway widening, where the state issued the permit therefor in the first instance.

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One of two 60 ft. dia. Reactor-Clarifiers pre-treating Colorado River water for the city of Page, Arizona. The site is the new Glen Canyon Dam, a U. S. Bureau of Reclamation project.

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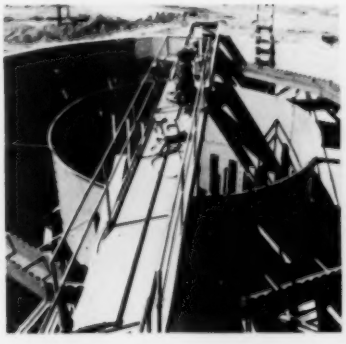

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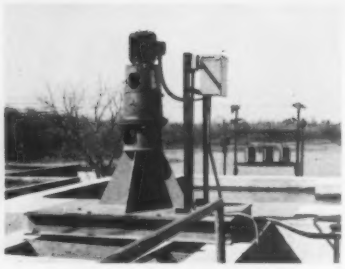

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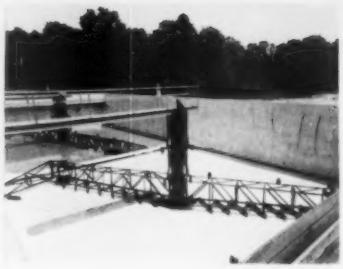

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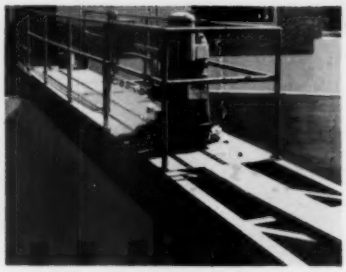

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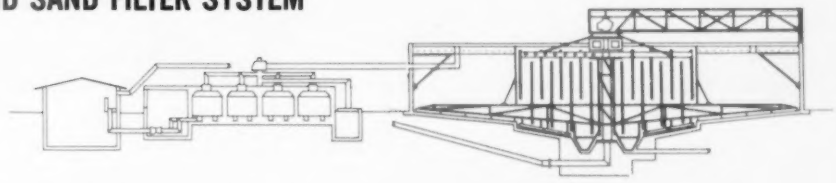

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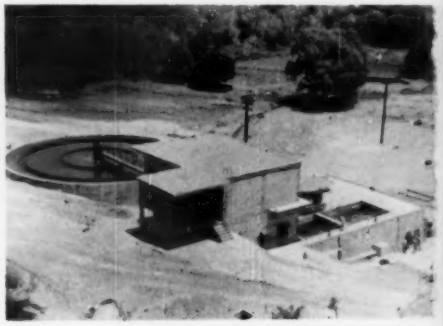

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Customer Relations

by THOMAS W. MOSES
President, Indianapolis Water Co.

For over 40 years prior to 1953, the Indianapolis Water Company, through efficient, economical operation, and infrequent rate increases dictated by the general economic trend during that period, enjoyed excellent relations with its customers. However, the rapid inflationary trend that occurred just prior to, and during 1953, had taken its toll by reducing the company's rate of return to substantially below 4 per cent. This, of necessity, required direct and positive action, and in September 1953, a request for a rate increase was filed.

The petition for a rate increase, coupled with the fact that only a few months before, control of the company had passed from the Geist Estate to the Murchison Brothers of Dallas, Texas, indicated that its customer relations were headed for difficult times.

The Problem

Indianapolis is a City of less than 500,000, with slightly more than 600,000 in Marion County. The water company serves slightly more than 500,000 people. There are three newspapers in the city and the competition among them is quite keen, despite common ownership of the morning and one of the evening papers. On most issues that can be classed as "popular", all three papers frequently end up on the same side and the competition is evidenced by the degree of intensity with which they attack the opponents of the cause they champion. This does not mean that these newspapers are unfair, but they are determined and particularly resentful if they suspect that information is being withheld.

As had been suspected, literally dozens of adverse editorials and cartoons appeared in each of the papers between the filing date of the rate increase, September 1953, and the final affirmance by the Supreme Court of Indiana, January 11th, 1956. Absentee ownership was one of the main targets.

Counter-balanced against these blasts were a highly respected management. Mr. Howard S. Morse, who had been the manager and operating head of the Company from 1925 to 1949, had been brought back from retirement to become president. During this period, there was never a suggestion that management was in any way responsible, and as a matter of fact, the general comments indicated sympathy towards management, and it was intimated that they were being badly used by the rapacious Texans.

Despite this countertrend, and a certain amount of sympathy for management, it was inevitable that the reputation of the Indianapolis Water Company would suffer.

Ascertaining the Facts

In May 1955, management decided to determine just what the public's attitude toward the company was. This date was selected because of a lull in the rate proceedings, and the newspapers had been reasonably quiet.

The Market-Opinion Research Co. of Detroit was employed for this job, and their report was based on a thousand personal interviews. The probability sampling was obtained by selecting blocks using a statistical method which resulted in a cross-section of the entire area serviced by the Indianapolis Water Company. Personal interviews were made with a designated number of householders at each selected location. In order to include a representative number of men in the sample, some interviewing was done during the late afternoon and early evening hours.

Needless to say, the results of the survey showed an unfavorable attitude toward the company.

Corrective Measures

In spite of resistance interjected by the lawyers, because of the fact that the company's rate case was still before the Court, the company embarked in September, 1955, on a positive and expensive public relations advertising program.

It was decided that the excellent newspaper coverage of the company's service area would provide the best media. This, plus the fact, that institutional advertising is difficult at best, and a visual presentation was the most effective type. Local models were used and the whole campaign was keyed to the friendly service that the water company was trying to perform for the community. Television was ruled out as too expensive.

Commencing in September 1955, the campaign consisted of 7-column ads, of which approximately 60 per cent of the space was devoted to a picture and the other 40 per cent to the text of the message and a "water quiz", in which questions about the company's business were asked and answered. At the beginning of the advertising program, the 7-column ads were followed by repeats of the same ad of half-page, 5-column size the following month. All three local newspapers were used, and this program provided once-a-month frequency, with larger and more eye-catching ads appearing every two months.

Concurrent with the advertising program, an independent public relations firm was employed to study and revamp the company's communications system with the local press. After an analysis of the problems, by the firm, the company was able to become more relaxed in its dealings with the press and entertained the editorial staffs of all three papers when an appropriate occasion arose. One of the main features to come out

of this new relationship was the terrific impression made upon the local newspapermen when they were shown the magnitude of the Morse Reservoir project, which was within 30 miles of most of their homes, yet not one of them had seen it before. Since that first visit, a party for the working press at Morse Reservoir has become an annual event.

As an additional step in the public relations program, 10 per cent of the company stock, held by the Murchison Brothers, was sold to local people in March 1956, and in April 1956, two local men were added to the Board of Directors.

Second Survey

In May 1956, Market-Opinion Research Co. conducted a second survey of public opinion, being extremely careful to use the same questions on a different cross-section of the service area in order to have a standard for comparison.

The results of this survey were so favorable to the company that the re-run of ads in the newspapers was cancelled and the program expanded to include radio spot announcements. The radio campaign consisted of amusing spot announcements which always ended in a bubbling sound depicting a man going under the plentiful water made available for the citizens of Indianapolis. These spots created quite a lot of favorable comment.

Third Survey

In May 1957, a third public opinion survey was conducted. One disappointing aspect of the results was the fact that while 94 people in 1955 thought the company was doing the best job of preparing for growth, only 61 thought so in 1957. It is significant, however, that all utilities suffered a corresponding decrease in favorable votes and the peculiarities of the sample undoubtedly affected this result. Finally, of the entire sample in 1957, 451 people noted the advertising, of which 90 said that they were influenced by it, and only two reported that they were unfavorably influenced. Any logical projection of this figure would suggest that 54,000 people in the water company's service area were influenced by the advertising, and of this number, almost 52,000 were favorably influenced. In Indianapolis, this is a large segment of public opinion, and it is reasonable to assume that even a higher percentage of the "thought leaders" were influenced if the non-objective standard of personal contact can be controlling.

Indianapolis Water Company
Public Opinion Surveys*

	1955	1956	1957
Feeling Toward Company:			
Favorable	798	901	935
Unfavorable	148	59	54
No Opinion	54	40	11
Rates:			
Reasonable	484	619	679
Too High	417	276	246
Service			
Excellent or Good	927	.....	959
Excellent	356	.....	450
Profits:			
Just Right	184	283	394
Too High	239	169	126
Too Low	3	11	11
Ownership:			
Municipal	388	.....	322
Private	315	.....	428
No Opinion	296	313	240

*All results based on 1000 interviews.

Conclusion

An attempt has been made here to present one approach to a problem common to all water works companies today. The brutal realism of present-day economics forces any thoughtful person to the conclusion that the private water industry is caught between the upper millstone of too low unit price and the lower millstone of inflation.

There, the private water companies must have considered understanding of its problems by the regulatory bodies. We, at the Indianapolis Water Co. feel that such understanding has its roots in keeping our customers informed of our problems and our efforts to solve them, with this educational process being carried on in a friendly atmosphere. Perhaps this is a radical departure from the traditionally frugal operations of most water companies, but the Indianapolis Water Co. feels that the financial risk was well worth the gamble.

Legal Aspects of Stream Pollution

By CARL E. GEUTHER

Legal Department, E. I. du Pont de Nemours & Co., Wilmington, Del.

Blackstone is reported to have said: "The law, like the River Thames, is always there; but its component parts are ever changing."

That this analogy is true is fortunate; nothing could be worse than to have man's destinies, his needs, and the economic factors that control his life bound by rigid inflexible rules of law. It has been well said that law was made for man, not man for law; and the mandate of adapting the applicable legal principles to changing conditions is a happy one.

In the field of water rights and obligations that adaptability of the law is now being met and it is predicted that within the next 25 years much of the earlier concept of law will be discarded for more workable legal theories. This is a necessary concession to the scramble for usable waters and the need for disposal of wastes and sewage accentuated by the vast industrial and urban growth of the country.

It has been said many times that of the natural resources water has become the number one concern of the nation. In more and more areas the steadily increasing demands for water are exceeding the available supplies. In the past year more than 1,000 cities experienced domestic water shortages. Many industries are finding it increasingly difficult to secure suitable water to maintain production.

It has also been said that water deficiencies can be met in part by impoundments to even out stream flows, but by and large the solution will be conservation of water quality through abatement of water pollution. It is becoming extremely important to purify used water from cities and industries to the extent needed to permit repeated reuse as the streams flow from city to city and from industry to industry.

It is proposed in this paper to limit the discussion of water pollution abatement to a brief review of those concomitants of pollution—legislation, litigation, and the law.

Background

Impelled during recent years by the growth of industry and the concentration of population in cities, state legislatures and the Federal Government have given more and more attention to legislation to curb pollution in both air and water. In 1953, 76 bills involving water pollution were introduced in the various state legislatures. In 1954 it was 42 water bills; in 1955 it was 119 water pollution bills; and in 1956, 32 water pollution bills were considered. What is the fundamental common law upon which this activity is superimposed?

If the problems of the municipality and its need for drinking water and sewage disposal are bypassed and comment on the prior appropriation theory of the arid West is withheld for the moment, the primary consideration becomes the riparian owner, one whose land borders on a stream. The law as to the respective rights and obligations of such a riparian owner is not new and comes to the present much as it was in the early 19th century when it developed under conditions peculiar to that time.

Nature of Riparian Right

If navigable tidal streams (and these are the main sources of water) are considered, the rights of a riparian owner are spelled out literally in thousands of cases. They are:

1. The right to be and remain a riparian owner and to enjoy the advantages thereby conferred on the land by its adjacency to the water.
2. The right of accession to the water, including a right of way to and from the navigable part.
3. The right to build a pier or wharf out to the navigable waters subject to any regulation of the state.
4. The right of accretions or alluvium.
5. The right to make a reasonable use of the water as it flows past or leaves the land.

Reasonable Use

The last right is the polestar here under consideration. The river bank owners, designated among each other as upper or lower riparian owners, dependent on their respective positions upstream or downstream from each other, have always had some right of use of the waters. These rights have changed perceptibly with the times and further changes are clearly indicated. During the formative years of the country's growth a doctrince known as the Natural Flow Doctrine entitled each owner to have the stream flow by his property in its natural flow, thus limiting all upper riparian owners to domestic uses, as anything else would impede the natural flow.

This has given way to the Reasonable Use Doctrine, whereby each owner may make reasonable use of the waters, a concession to industrial needs. Using this principle today a riparian owner, although he does not have any ownership in the waters themselves, which are held in trust for all users by the state, nevertheless enjoys an increase in the value of his land, which attaches by virtue of the fact that water runs along or through it. Today the natural flow theory, although still mentioned in some of the cases, has given way to this right of the upper proprietor to make a reasonable use of the water, and whether a use which affects the purity of the water is reasonable in a particular case is a question of fact to be determined by a consideration of the character of the stream and its ordi-

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nary use, the extent of the pollution, its necessity for the purpose of making beneficial use of the water, and the resulting damage to lower proprietors.

The nature and extent of pollution that would permit legal intervention is not always easy to determine. All running streams are, in a sense, polluted and the very term must be understood in a comparative sense. No owner does receive nor can he reasonably be expected to receive the water in a state of entire purity. Any use, however, that materially fouls and adulterates the water so as to impair its value for the ordinary purpose of life will be deemed a violation of the rights of a lower riparian owner.

Navigable vs. Non-Navigable

The rights of an owner on a navigable stream have been mentioned heretofore as opposed to those on non-navigable waters. In the former the owner owns only to the low-water mark and has no ownership in the water itself. That is owned by the state in its sovereign capacity and is held by it as trustee for the public, to permit navigation and, heretofore, the removal of urban sewage. The riparian owner had merely to usufructuary interest in that water, a right to use it reasonably.

As to non-navigable streams, the riparian owner owns the bed of the stream and shares the ownership of the water as it passes his land. Because the ownership is more absolute in this type of case, claims for damage or suits for injunction are more successful than with respect to navigable streams—where the right to pollute has, heretofore, been largely conceded—as a necessity for carrying to the cleansing action of the high seas the garbage and filth of cities.

Trend in the East

For many years people in the East have had an abundance of water and have been profligate. The 17 Western States have faced the problem of shortages for a long time and have achieved the best answers through the prior appropriation doctrine, which grew up by custom, and by which the first user gets priority over later users. By this means they avoid the uncertainties of the riparian doctrine, as they always know how much water is left after the users who are prior in point of time are satisfied. It seems evident that the East is going to ultimately reach some phase of that doctrine, and water rights ultimately will be based on a dole system by which some state or authorized private agency will parcel out the water rights in its particular watershed.

Having grown up under the riparian rights theory the author recognizes this inevitability reluctantly, but it is evident that the riparian right of reasonable use in breaking down in the East through greater consumptive demand for water.

Nature of the Remedy

The nature of the remedy (that is, the type of legal action maintainable by the injured party) can take different forms, as follows:

1. It can be a suit for damages.
2. It can be a bill for injunction to prohibit further pollution.
3. It can be a criminal prosecution for a misdemeanor.

Legal Action

If the pollution creates a public nuisance the Attorney General is the proper party to bring an action and can proceed to enjoin on behalf of the state. The State Department of Health is the final enforcement agency.

However, it should be mentioned that in some states the game wardens have a considerable amount of power and supervision over pollution. They are officials of the law and can make arrests just as any other member of the police force. They can arrest a pollution violator and take him before a magistrate.

Injunctions

Because the trespass resulting from pollution of the stream is in most cases by its very nature a continuing one, the only remedy of any long-range value is an injunction. In order to entitle a riparian owner to injunctive relief, however, he must show not only that the defendant threatens or makes an unreasonable use of the stream waters, but he also must establish the further facts which entitle him to such relief under the general equitable principles applicable to injunctions. To most people concerned with the operation of an industry "injunction" is a word that send cold chills down the spine. Obviously, it can spell sudden death for a vast manufacturing enterprise and, accordingly, if damages can be adequately compensated by a money award an injunction will not be granted.

In the past the trend was toward such granting, since to merely assess the repeat offender with an award of damages had the practical effect of granting him the power to eminent domain—the power to take the property of others hitherto reserved for the state. However, a change in this trend is predicted, as modern civilization demands that certain minor property rights must give way to progress in the form of vital industrialization.

In fact, a review of the law in 32 states reveals that 14 of them—almost one-half—have adopted the comparative injury doctrine and will refuse an injunction where the injury to the offender by injunction is much greater than the damage to the plaintiff by the pollution. This doctrine is sometimes called balancing of convenience or public interest doctrine; an apt illustration is the situation in Pennsylvania, where the coal mining industries were sued for injunctive relief and it appeared that the result would be the closing down of an inmportant industry. The Court there noted that the miners had to locate where the coal is situated and the possibility that to award damages for polluting the stream would result in the closing down of the industry was too substantial and an injunction was denied.

However, where the threatened or actual pollution has amounted to a public nuisance as opposed to a private nuisance, the public interest factor or balancing of conveniences has carried very little weight. Behind the concept of the common law which has been heretofore discussed, it should be noted that it is no defense to one polluter who finds himself in court to argue that others also are polluting. This has been held to be no defense whatsoever.

Discussion

Before leaving the subject of damages and/or suits for injunction, it is well to note that of which all are basically aware, but which is sometimes lost sight of. That is the fact that a plaintiff who is aggrieved by pollution need not be a riparian owner, so that the subject of the consequences of pollution go far beyond the banks of the river.

To complete the current picture there must be added to the common law three types of activity that have become tremendously important in the modern-day concept. They are:

1. Statutes that impose liability for violations that tend towards pollution of streams.

2. Interstate compacts (Incodel and the Tri-State Sanitary Commission are examples).

3. Federal legislation and activity in the field of water pollution abatement, as exemplified by Public Law 660 passed by the 84th Congress, which is the ultimate result of Senate Bill 890.

Statutes

Of the statutes that are applicable in the State of New Jersey, for example, some have been on the books for many years. In general, they prohibit the deposit of explosives or poisonous substances in the waters of the state, and with particular reference to the Delaware River. They prohibit the dumping of polluted materials above the source of municipal supplies. They prohibit the deposit of sludge in the rivers of the state. In addition, there are specific statutes creating sewage commissions for the passaic and Hackensack Rivers, which are under the exclusive control of the respective commissions. The prohibition found in the Act creating the Passaic River Sewage Commission is rather broad and recites: "No sewage (waste matter) article or substance, liquid or solid, of any kind which creates odors, gases or fumes due to the putrefaction of organic matter or the presence of chemicals or which results in the presence of oil or grease on the surface of the waters of the Passaic River or its tributaries shall be deposited."

Although these statutes are of some help in combating pollution, they have not served as a very successful answer. Prosecutions under them have been few and far between and normally result in simply a conviction on the basis of a misdemeanor which results in a fine being levied.

Pollution, whether it be of water or air, is no respector of state lines and there is the problem of pollution that may occur or arise in one state becoming a factor of annoyance and even nuisance in another state. Along these lines, much attention has been given within the last generation to the creation of interstate compacts between the states that may surround a particular watercourse so that regulation can be had in each of the signators toward the end of abating pollution. This has been given the stamp of approval by Congress and brief reference is made to two of the outstanding ones.

Interstate Sanitation Commission

First, the Interstate Sanitation Commission comes into the review scope. In 1935 Congress approved an interstate compact between New Jersey, New York, and Connecticut for the purpose of abating existing water pollution and controlling future pollution in waters around New York Harbor and the boundaries of the three states. Pursuant to this compact the three states set up the Interstate Sanitation Commission, whereby the waters were divided into Class A and Class B, Class A being that in which recreational activities and shellfish abound, and Class B where these factors are not present. Certain standards were set forth for both types of waters and each state agreed to prohibit the pollution of the waters.

Pollution was defined as any foreign matter which renders the waters unfit to sustain fish life or unsatisfactory for bathing. Injunctive relief could be had and hearings could also be held whereby orders would be issued against the offenders.

This Act was amended from time to time after its original adoption by New Jersey and the Laws of 1935, Chapter 321. The more recent amendment to it was an effort to extend its control to air pollution, which again was no respecter of state lines.

Incodel

The idea of the Interstate Commission on the Delaware River Basin was born in 1936 because three of the area states—New York, New Jersey, and Pennsylvania—had been squabbling bitterly over which was entitled to the lion's share of the river waters. It came to life shortly after New York, New Jersey, and Pennsylvania had fought a two-year battle as to whether New York had the right to withdraw some 600 mgd from the upper reaches of the Delaware River as it passed through the state.

With that problem solved by Supreme Court decision, it was recognized that some sensible approach had to be taken toward the utilization and rationing of the waters. As Supreme Court Justice Holmes said in his classic contribution to the literature of the law: "A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it. The different traditions and practices in different parts of the country may lead to varying results, but the effort always is to secure an equitable apportionment without quibbling over formulas."

After a number of years Incodel's efforts culminated in 1949 by the adoption of legislation by the various member states, charging Incodel with the responsibility of conducting such surveys as would be necessary to determine the feasibility and advisability of the future construction of an integrated water project within the Delaware River Basin above Trenton for the mutual use and benefit of the basin states. Delaware has also joined Incodel and the river has been divided into various regions, with different standards of purity being applicable to the various section or sectors with, of course, the greater pollution being permissible as it nears the sea in its course.

Federal Legislation

When the United States Congress adopted Public Law 660, which is the final draft of Senate Bill 890, many were bitterly opposed to the advent of the Federal Government in water pollution abatement activities. However, the opposition was not successful and the first bill passed was the Water Pollution Control Act of 1948. Public Law 660 was merely an amendment and extension of that law by which further powers were given to the Department of Health, Education and Welfare. By the amendment of S 890 (or Public Law 660), the United States was empowered to take certain action on the request of any state that felt aggrieved by the activities of another state. This deleted from the original act the requirement that the offending state must also request that such action be taken.

There has been considerable feeling that the Federal Government should have no part in the regulation of pollution in the various watercourses. Despite the fact that there is an interstate characteristic involved,

the thought has been that the various states, either through interstate compacts or by their own actions and legislation, are entirely capable of controlling these problems, and that the matter of states rights is vitally concerned. States rights may sound like a wornout theme, but actually it is the right of local industries to be governed and standardized by local citizenry rather than to have a Congressman from, say, an entirely different area or a health department official from a distant state passing on what is good for a specific, localized area.

Results

The end results of this type of activity, which has been superimposed on the common law rights, are as follows:

1. They have set certain limits on the permissible pollution.

2. Because the violation of regulations or statutes constitutes negligence *per se*, the advent of the statutes and compacts has simplified the quantum of proof necessary for the successful prosecution of lawsuits.

3. Their advent has paved the way for more frequent action by state officials or Commission officials in the nature of a collective or public suit for the abatement of nuisances.

Conclusions

As the company lawyer looks at the problem, facets other than the strictly legal ones fall into sharper and sharper outline. It is entirely appropriate that the lawyer—and, in fact, everyone representing industry directly or indirectly—consider as basic and fundamental the following:

1. The laws, both common and statute.

2. The public relations aspect of being a good neighbor and an integral part of communal affairs.

3. The economy of usage, to insure that an adequate supply of usable water is available for all industry and the public, in spite of unheralded expansion.

To conclude, policy consideration on purely legal premises invites misjudgment and is an approach to be frowned upon. The limit of what the existing law allows in degrees of pollution is no longer the sound test for industry, which has both a public relations and a self-preservation stake in its activities.

The various legal doctrines—Natural Flow, Reasonable User, Comparative Injury, and the like—all must be remodeled on a mid-20th century scale so that mankind can live with the law. It is impossible to continue under a system that today may place an investment of many millions of dollars at the mercy of the activities of an upper riparian owner; but in reverse fashion neither should the upper-stream owners be hamstrung in order to give special consideration to the one at the mouth of the river where it meets the sea. Happenstance of location should never become the deciding economic factor in the use of water, a common heritage. Happenstance of priority has many fallacies, such as foreclosing future users merely because, as individuals or corporations, they were "born too late." Nevertheless, it at least approaches a certainty as to the amounts involved and will prevent over-expansion of a watershed with possible ultimate ruin to all users.

The threshold of a new era is evident in many fields, but none is so vital yet so commonplace as that of water rights. The laws must and will be molded to achieve a satisfactory balance of interest, individual against individual, public against individual, and in the general over-all public interest. There is no greater factor bearing on the satisfactory solution of these problems or the proper molding for the future than intelligent cooperation on the part of industry, regions, states, and even countries, which also can be selfish and greedy as to the use of this valuable resource. Avarice is not restricted to individuals; it can be country-wide, statewide, or even international in scope. Problems of this kind, either local, national, or international, cannot be satisfactorily solved by a lawsuit or guns, yet wars have been fought for less. And even the courtroom, with its narrow perspective of litigation between two, or at best a few parties, is not the place for solution.

Water and other natural resources

By EARNEST BOYCE,
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A study of the principles and philosophy of the laws that now govern the actions of society in dealing with our water resources, has at long last, been started.

As the need for water utilization develops to the point of competitive demand, our best interests will be served by the further evaluation of the functions that this resource must perform and an extension of the principles of law that will establish the orderly procedures necessary for the highest development of this resource, consistent with society's economic needs.

When we tabulate the natural resources that man, with science-directed skill, has utilized to build the foundations of the economy that we know, we may classify these resources in many ways—all of them except water.

As a resource, water is a requirement so basic to man's existence that all other resources are either dependent on its plentiful supply or, in its absence, valueless for man's use and development.

Our lands, with their capacity to produce our abundant food supplies, our forest and fiber needs, and all the renewable resources of organic growth, are dependent for their productiveness on the timely availability of this resource. The conversion of our mineral resources into the useful products of our manufacturing industry cannot be accomplished without the availability of the necessary quantities of process water.

Finally, we should note that man, himself, as a living being, requires the constant availability of safe, palatable water for his physical and domestic needs. And, through a knowledge of modern sanitation, he has learned the health and comfort advantage and necessity for the water-borne removal of the wastes of human habitation and of industry.

Most Water Uses Are Not Consumptive

While many of our natural resources vanish with use, most water usages produce changes in the position, quality, and/or quantity of the water, depending on how it is used. The multiple usage of the resource, water, within one hydrological cycle, is frequently an economic necessity.

Water power energy may be recovered from a change in position of the water as it moves on its way by gravity to some lower elevation. This energy recovery may not offer serious water use competition so long as other energy sources are available, for the water remains unchanged in quantity and in quality. This is not a consumptive use of the resource.

However, many of the necessary uses of water do produce changes in either its quality or quantity. A change in quantity is usually the result of evaporation or transpiration loss, as for example, in irrigation, lawn watering, evaporative cooling, and non-condensing steam production. Water quality changes are produced when the use of the water causes it to pick up and carry, in solution or suspension, substances not previously present. The water resource significance of this change in quality is to be found in the cost of the reprocessing of the used water for subsequent re-use, or in the possible limitation of the re-use potential due to the fact that the reprocessing procedures of water purification, including sewage and industrial waste treatment, do not effect a 100 per cent removal of substances that may have been added by its usage.

Pollution Prohibits Reuse

With the increased demands for the use of water in the many manufacturing and industrial processes, a new form of what might be regarded, for lack of a better classification, as a consumptive use of water, is emerging. When an industrial process so changes the quality of water as to make it unfit or unsuitable for further re-use, and when known water treatment processes, short of evaporation, are unable to remove the effect of its prior use, not only is that volume of water effectively consumed as regards its potential re-use, but, unless confined in permanent storage, it has the capacity to deteriorate the quality of the diluting water into which this indus-

trially used water is discharged. The process water used in the preparation of our atomic fuels is one example of this type of water usage and there are many others.

Constant Availability Unpredictable

However, it is not so much the varied ways that water may be used that set it apart from other natural resources. Rather, it is the unpredictable variations in the quantity available from rain or snowfall in any period of time and in any locality. While no natural resource has been more amenable to man's control than water, no resource has so baffled him with its cyclic variations of flood and drought. As usage demands approach or pass the available water supply in periods of drought, a shocked public concludes that the water resources are failing and that something must be done about it. Then, suddenly, the picture changes and floods replace the shortages and public interest ebbs.

Because the usage demand of industry and the domestic water supply of industrial areas continue with some degree of uniformity through seasons of drought, it follows that this demand must be supplied from some form of natural or constructed storage, or a combination of the two, so that waste flood waters can be controlled to equalize the source of supply.

Because of the ever increasing demands for water to supply the needs of an expanding economy, well planned expansions of suitable and economical water control measures are becoming increasingly important.

In certain of the arid sections of the United States, where the availability of water controls land use, water control development has approached an economic limit that is fixed by the increasing cost of storage over a lengthening period of time as more and more of the waters of the less frequently occurring floods are impounded for use.

While the situation in the more humid regions of the United States is, in general, less critical, a failure on the part of those who plan the expansion of certain industries, with heavy water use demands, to recognize the economic significance of the cost of water supply development to meet these demands, may easily create serious local supply problems.

Increasing Usage Creates Legal Problems

The present interest in the legal aspects of water use and control stems, in part, from an awakening realization that the once ample water resources of the eastern states are in certain areas no longer adequate, without further development, to meet the maximum use demands being placed upon them. In many instances, a regulation of flow through the construction of storage facilities may be indicated. In other situations, heavy water control expenditures might be avoided if some legal restriction were to be imposed on the development of certain land areas for usages that will require unusual volumes of water. In other words, many of our water shortage problems in this section of the United States are man-produced in that too often there has been a tacit assumption that the existing water resources were adequate for any land development need.

The availability of water for use or development and the possibility of discharging used water, without damage to others who may be dependent on the receiving body of water as a supply source, and at a cost that can be borne by the development creating the demand, should be established as a basic criteria to be met by all who plan changes in land use.

More Basic Hydrological Data Needed

Unfortunately, the basic hydrological data needed for a reasonable evaluation of the water resources of many important river basins are too inadequate to provide a sound basis for planning the developments needed to meet future requirements.

The Commission on the Organization of the Executive Branch of Government, known as the Hoover Committee, as the result of its study of water as a natural resource, noted that "It is self evident that if a water resource project is to yield maximum benefits at the lowest possible costs, its planning and construction must be based on adequate and reliable data concerning all social, economic, and physical aspects of the project." The report goes on to state that "The really disturbing thing is that so little progress has been made in obtaining reliable hydrologic data in advance of project planning and construction. Though the necessity for more adequate data has long been recognized, we find ourselves embarking on the most gigantic water projects ever devised, with alarming gaps in our knowledge of the probable behavior of the waters we are trying to control and utilize. So serious are these deficiencies that it is estimated, on the basis of experience, that the limit of error or ignorance in present water developments is rarely less than 25 per cent and is frequently greater than that.

"Present knowledge of the relationships among precipitation, runoff, evaporation, ground water movement, soil condition, vegetal cover, transpiration, etc., is far from complete, but our greatest shortcoming has been the failure to provide sufficient funds for the utilization of rain gages, snow surveys, stream flow measurements, evaporation stations, runoff and erosion studies, ground water observation wells, water quality analysis, and other established methods of obtaining data essential to the planning and construction of river development projects.

"Continuous application of these techniques over a period of years is required to furnish reliable data, yet not infrequently, the first intensive efforts to apply them are coincidental with the commencement of a project study. Few areas are even adequately mapped for water development purposes."

Unless these basic data are obtained in advance of development, there can be no sound basis for the allocation of the water resources. The collection of scientific data has little popular appeal and many state budgets fail, as the Hoover Report indicates, to make reasonable provision for obtaining data that must be collected over a period of years to have design value. The proper development of water resources, both from the standpoint of increasing the quantity available during periods of drought and the control of flood damage, is a matter of real public concern. It is important, therefore, that conferences should give consideration to legislation that will insure the establishment and financial support of these necessary and permanently continuous fact-finding agencies of the state and federal governments. We must know the measurements of the resource before we can hope to allocate its use with wisdom and judgment.

If water use allocation were to be limited to the quantity available from the normal uncontrolled flow of surface water and from ground water pumpage in a river basin, it is obvious that the limit of allottable usage would be that available during the minimum flow period modified by ground water storages, and, therefore, much of the potential water resource of the basin would be lost. It follows that the allocation of water usage in amounts in excess of this minimum uncontrolled discharge would require that there be an analysis of upstream flow regulation including a determination of its engineering and economic feasibility.

Planning Should Encompass Entire Drainage Basin

The source of water as a usable resource is the rain and snow that falls on the catchment area of a river or lake basin. Consequently, the land and water area of a drainage basin forms the natural areal unit for the study of the various ways that the waters of the basin can be controlled for flood protection and for use and, in some instances, for multiple re-use.

Depending on the topography and geological formations, river basins vary widely in their capacity to naturally equalize the discharge rate of rain and snowfall. The filling and subsequent drainage of permeable formations in the river basin provide the dry weather river discharge. These formations also provide the below-ground water storage, recoverable through the use of wells. In some basins the storage capacity of the permeable formations may approach that necessary for a full control of the river discharge. In other basins the storage potential of river valley aquifers can be greatly increased through a development of recharge areas tributary to well fields.

The planned development of the water resources of any river basin requires that all these basic factors be studied as an integrated unit. While public and economic interest in the water may vary along the course of the river draining the basin, it is the same runoff water that passes each section of the valley and changes in its quantity and quality are the product of its control and use through the length of the valley.

The destructiveness of our floods is evidence that the developed land usage of the flood plains of a river is competitive with the need for the same flood plains for the passage of floods that originate up-valley.

Not only should the development of the water resources of a river basin be studied as a unit and a mutually acceptable policy of use and control be developed, but public works based on these studies may need to be basin-wide in their scope to secure the highest development of the water resources of the valley; again, consistent with society's economic needs.

Aside from flood control, much of the legislation authorizing the development and financing of public works relating to water resource development has been enacted to meet the situations that confront cities and other political subdivisions concerned with a definitely local water supply problem. Water supply has been too long regarded as a utility problem having localized interest. Consequently, each unit of local government has been compelled to operate within its limited jurisdiction to secure the water supply development that its growth requires. There appears to be a need for an operable and functional agency of government with the freedom of action necessary to coordinate the varied interests of a river basin into a unified plan.

Conclusion

In these remarks, an attempt has been made to point out some of the special problems of water control and development that make this resource inherently different from others and to indicate a few of the legal aspects of these special problems.

This is not a new field of research and investigation and many excellent studies have been made by the agencies of the several states and by the federal government.

It is hoped that as the result of this conference, some new thought can be brought to bear on this important subject, some concept of how to integrate what we know about water resource development into a workable and legally acceptable way of acquiring, under the democratic procedures of government, the benefits that can be had.

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SAFETY IN WATER AND SEWAGE PLANTS

BOTH THE AMERICAN Water Works Assn. and the Federation of Sewage and Industrial Wastes Assns. have published manuals on safety. The Federation's Manual of Practice was published in 1944; the AWWA Manual appeared in the Journal in 1955.

Need for Safety Program

Statistics gathered by the National Safety Council show that the water works industry has a higher rate of frequency of accidents than the gas, electrical or communications industries (in that order) and the severity rate is second highest. Data on sewage works has not been summarized but there is little reason to believe that the frequency of accidents is much less than in the water works industry.

Frequency is the number of disabling accidents per million man hours worked. In water works, data indicate the frequency rate to be 23.19 whereas in the communications industry it is 1.22. The severity rate (number of days lost per million man hours worked) is 930 in water works, while in the electrical industry it is 1550 and in the communications industry, 100. The fact that water and sewage plants employ relatively few men does not help the situation. National Safety Council data indicate that utilities with less than ten men have a frequency rate of 17.2 and a severity rate of 2700, the highest observed.

Causes and Costs of Inquiries

Handling objects is the source of more accidents than any other cause. This is followed by falls, falling objects, machinery, tools, etc. Injuries to the body lead the list, followed by injuries to the fingers, arms, hands, feet, head, eyes and lastly toes. toes.

Types of injuries occur in this order: bruises, contusions, cuts, lacerations, sprains, strains, fractures, burns and eye injuries.

The AWWA has shown that the cost of accidents are computable and occur in at least ten categories:

Time lost from work
Loss of future earning power
Economic loss to employee's family
Time lost by other workmen
Efficiency loss because of break up of crew
Time lost by supervisor
Cost of breaking in new employee
Damage to tools and equipment
Time damaged equipment is out of service
Spoiled work

These causes and costs of accidents are just as applicable in sewage and industrial waste treatment plants.

A Safety Program

The benefits to be gained from safety practices are many: improved efficiency, improved service, increased earnings, better employee morale, better public relations, and savings in the direct outlay for costs both by the utility and individual.

The AWWA Manual includes a section on how to set up a safety program and how to maintain it. The Federal Manual of Practice No. 1, likewise sets forth specific steps, and rules for a good safety program.

Steps to Prevent Accidents

1. Keep a record of all injuries, source, cause, result, cost, time lost, etc.
2. Make it a habit to look for hazards.
3. Correct any unsafe condition no matter where it exists.
4. Interest all employees in safety as an important factor in employer-employee relations.
5. Teach employees good work habits.

Safe Working Practices

The AWWA Manual contains 23 sections dealing with every possible operation or function in a water works and a full list of references on safety information.

The Federation Manual devoted most of its content to the prevention of dangers from noxious gases, vapors and oxygen deficiency and discusses how the prevention of physical injuries is related to design, safety equipment and safe practices. Information is organized under sections on sewers, pumping stations and treatment plants. Prevention of body infection is covered in relation to frequency of infection, plant design, safety equipment and safe practices.

References

The AWWA "Manual on Safety Practices for Water Utilities" may be obtained from the Amer. Water Works Assn., 2 Park Ave., New York 17, New York.

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Organizing a Safety Program

by MARK B. WHITAKER

Gen. Mgr., Knoxville Utilities Board, Knoxville, Tenn.

PROTECTION of employees from accidental injury and damage to health is a responsibility of management. Modern management accepts this responsibility, and if any justification is needed, the following reasons for it may be cited:

Legal obligation. All states have laws that require employers to compensate for injuries suffered by their employees while on the job. Also required are reasonable safety standards for employee protection.

Social responsibilities. A safe working condition is a moral obligation imposed by society. The increasing emphasis on accident prevention has been evident for many years. Management which fails to accept this responsibility will find that public opinion will support additional government regulations.

Economic necessity. Accident prevention is simply good business. The prevention of an accident costs less than its expenses—a fact that has been proved many times in the experience of thousands of industrial operations.

Safe working conditions and accident prevention can be accomplished only by the organization and the coordination of efforts of all concerned. The functions of a program to accomplish this objective are usually planned by the staff and administered by the line organization.

Frequency Rates

Organized safety programs in water utilities are comparatively new. Other utilities such as those in communications, power, gas, and transportation have had them for longer periods. The lag in water utility programs is partly a result of the fact that water works are generally small and have been operated as part of the municipal government rather than as an industry.

In 1945, the accident frequency rate in water utilities was approximately 35.46. This means there were 35.46 disabling injuries for each 1,000,000 man-hours worked. The latest figure available (1954) indicates that this frequency has dropped to 17.18, or about one-half of the 1945 rate. With such results, there seems to be no reason why water operations cannot establish a frequency rate comparable to industry or to other utilities. In 1954 the general industrial frequency rate was 7.22; the gas utilities rate, 10.51; the electric utilities rate, 8.62; and the communications frequency rate was 1.30.

Planning a Program

Planning and organizing a safety program presents a number of problems. The Knoxville Utilities Board, Knoxville, Tenn., has recently undertaken to plan an overall program which brings out many of the problems involved. The board is made up of three operating units: the Bureau of Power, Bureau of Water, and the Bureau of Gas. The fourth bureau, the Bureau of Accounts, administers the accounting for the three operating bureaus. Each of the operational units has its own individual needs and procedures and these may differ from those of other bureaus. A safety engineer, reporting to the general manager, was selected to head the safety program for the entire board. He acts in an advisory capacity and handles all safety problems and procedures directly with the bureau superintendents, as they are charged with the authority and responsibility of their bureau operations, and he in turn keeps the general manager advised of the actions, procedures, and practices of each bureau.

The safety engineer has a secretary and a safety supervisor in the power bureau; another safety adviser has a joint responsibility of the water and gas bureaus as their maintenance and operation problems are somewhat similar. The safety supervisors are responsible for promoting safety in the divisions assigned to them.

Initial Implementation

The first step was to revise the rule books, so that, rather than being safety rules, they were prepared as a book of instructions and were issued as orders under the signature of each bureau superintendent. When a safety procedure is violated, therefore, the employee is not breaking a rule but disregarding orders. This gives the foreman and safety supervisors the backing they need in enforcing safety practices.

Each employee is given one of the instruction books and signs an agreement to abide by the safety instructions as long as he continues to be an employee of the board. He is required to know the instructions pertaining to his particular bureau, and from time to time questions or quizzes are given in order to be sure that the employees and supervisors are familiar with safety requirements.

Reporting and Investigating

The next step was to centralize accident reports and records. Accident reports concerning employee injury, public liability, and motor vehicles, are made out in the department in which the employee works, and a penciled copy of the report is forwarded to the safety engineer who makes additional copies. Copies are sent to the insurance carrier, the bureau superintendent, the division head, the safety supervisor, and the

personnel director, and a copy is retained by the safety engineer for his files so that everyone in the organization concerned with the responsibility for the accident, or actions necessary to be taken resulting from the accident, has factual information for action.

The next step, which is essential in any safety program, is the investigation of accidents. Each accident of any consequence is investigated by a committee composed of three employees in the department concerned, the department head, and the safety supervisor. The safety supervisor acts as secretary and records the minutes. This committee is a fact-finding committee only and reports the results of its findings to the department head, who takes all disciplinary action. The aim of the committee's action is to keep all parties concerned informed and to insure absolute fairness of any disciplinary action that may be required. The foreman is the key figure in any safety program. Foremen meetings have been organized in which not only safety, but other matters are discussed. These meetings are held at least monthly and from time to time in the meetings, a representative from the insurance carrier may be present, the board's attorney may discuss the Workmen's Compensation Act, or someone else may be there to discuss matters of safety. These meetings are held principally to emphasize the foreman's part in management and his responsibility in conducting a safety program.

Each month a report of all accidents is made, indicating progress or lack of ia for the previous month and year. Every supervisor and foreman in the board receives a copy of these reports, and copies are sent to the insurance carrier's safety engineer in order to keep him posted on progress and to take advantage of any suggestions that he may have to offer.

Other Incentives

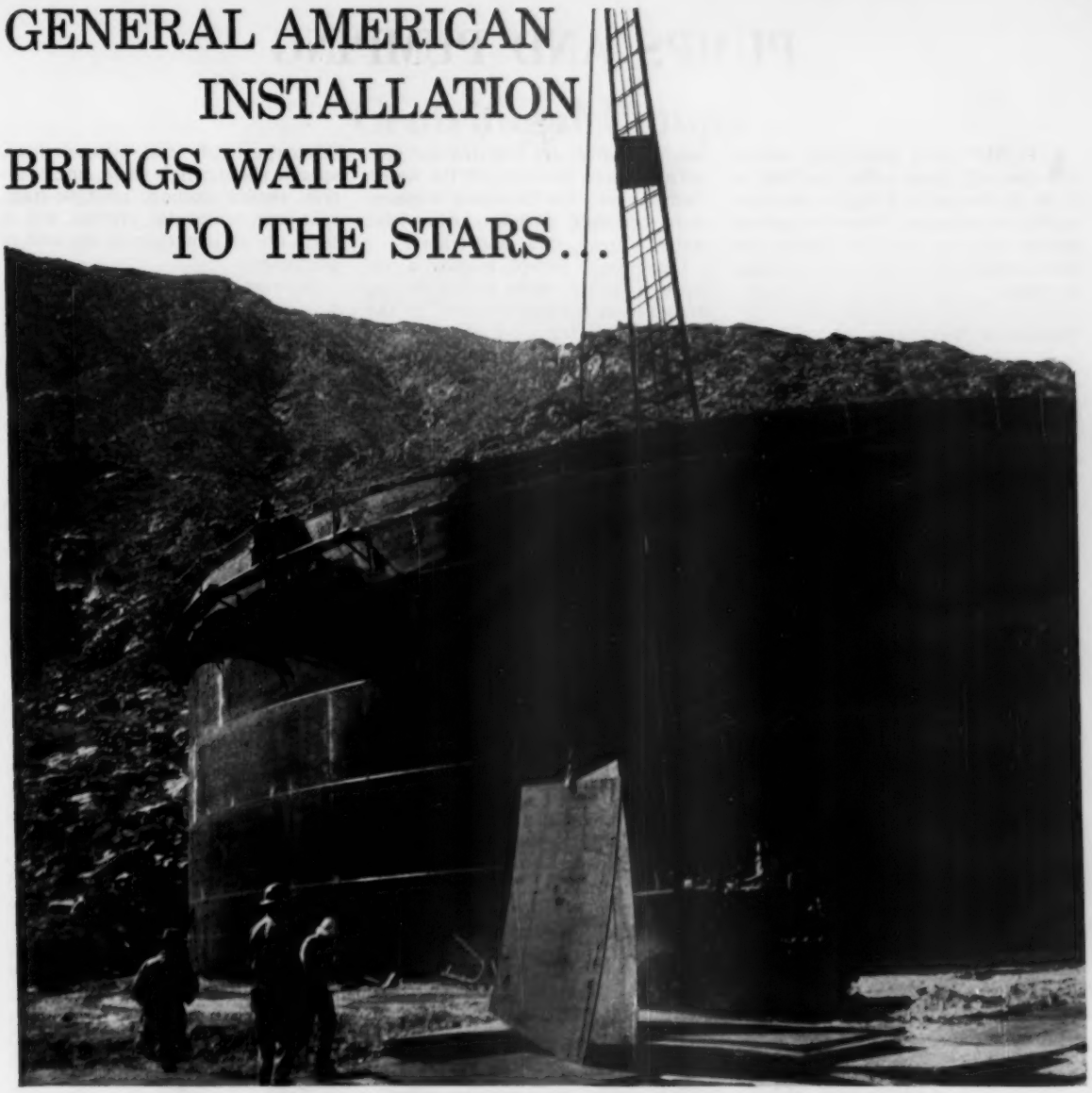
Each month the house organ, the *KUB Reporter,* has a column headed "Keep Your Name Out of This Column," in which all accidents, the name of the employee involved, his department, and a short description of the event, are given. A monthly safety letter is issued to all drivers—each letter conveying some suggestions on safe driving. The use of brakes, parking on hills, speeding, and maintenance of vehicles are the types of subjects covered. A safety suggestion box is kept in each department, and the employees are encouraged to offer any suggestions that will promote safety on the job.

Other means to stimulate safety thinking have been used—means such as outdoor safety banners, bulletin board safety posters, safety literature issued to supervisors, and safety articles in the house organ.

Conclusions

A safety program will be effective only if the cooperation of all supervisors and foremen is offered. If cooperation is lacking, only lip service will be paid, and no effective results will be shown in the reduction of accidents. Administering a safety program is not particularly complex compared to securing the cooperation of the employees who may realize the importance of their own safety, but are indifferent to the aims of management. Management must lead. If it is indifferent, employees will follow the example. Anything other than a planned persistent effort will be fruitless.

GENERAL AMERICAN INSTALLATION BRINGS WATER TO THE STARS...



Palm Springs is a thirsty city. In this desert playground of movie stars and sun-worshippers at the foot of water-rich Mt. San Jacinto are more gardens and swimming pools per capita than any other place in the world. Within the mountain are many underground streams. The problem was to tap the resources and store more water than existing reservoirs would hold. The answer—a 5,000,000 gallon tank fabricated in General American's shops, trucked to a hard-to-reach spot on the hillside and erected by a General American field crew.

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PUMPS AND PUMPING

A PUMP IS a mechanical device that will cause a fluid to flow, or to be discharged at a higher elevation or higher pressure. Power to operate pumps may be electricity, steam, internal combustion engines, waterfalls, or wind.

Reasons for Pumping

In a water works, pumps are used to:

- Lift water from a surface source of supply
- Lift water from wells
- Deliver water to consumers' taps at desired pressure
- Supply fire pressure
- Boost line pressure
- Fill elevated storage tanks
- Backwash filters
- Pump chemical solutions
- Dewater tanks, basins, sumps, etc.
- Provide boiler feed

In a sewage works, pumps are used to:

- Lift sewage from low areas to main sewers
- Lift sewage from interceptors to treatment plants
- Move sludge from settling tanks to disposal processes
- Recirculate sludge digestion tank contents
- Supply air to aeration processes
- Return activated sludge to process
- Provide digester tank gas to boilers or internal combustion engines
- Provide water for various uses including boiler feed and elutriation

Types of Pumps

Pumps may be classified by operating principle or by use. Operating principles include: Displacement, centrifugal, ejector, air lift, hydraulic ram and aorta.

Displacement pumps are a type in which water is caused to flow from the source of supply through an inlet pipe and valve into a chamber by a vacuum created by the withdrawal of a movable part, which on its return displaces the water in the chamber and forces it to flow through the discharge valve and pipe.

Displacement pumps are of two types: Reciprocating and rotary. In the reciprocating pump the movable part enters and withdraws from the chamber on the axis of the centerline of the chamber. Piston, plunger and diaphragm pumps operate on the reciprocating principle.

Rotary pumps consist essentially of a rotating element which fits closely in a case. The rotation alternately draws in and discharges water, with the discharge being opposite the suction. No valves are required and centrifugal force does not lift the water. Pumps which use the rotary displacement principle include: Gear, lobe, screw, Moyno, vane, and others.

Centrifugal pumps employ a rotating impeller, with water being drawn in at the hub or "eye" or the pump impeller and discharged through a spiral casing by virtue of centrifugal force developed by the rotation of the impeller.

True centrifugal pumps include the volute pump and the diffuser pump. In the volute pump the impeller discharges into a gradually increasing spiral case. In the diffuser centrifugal pump, the runner (impeller) is surrounded by gradually expanding passages formed by stationary guide vanes, which change the direction of the flow and increase pressure developed before discharging into a spiral casing.

Other pumps classed with the centrifugal pump, but not employing the centrifugal principle are the turbine pump, and the propellor or axial flow pump. The mixed flow pump develops its head partly by centrifugal force and partly by the lift of the vanes.

Pumps using other principles of operation are the ejector or jet pump, air lift pump, hydraulic ram and aorta pump. Jet and air lift pumps are used for deep well pumping; the hydraulic ram is used for small water supplies; the aorta pump is used for sampling or pumping small volumes of chemical solutions.

Uses of Pumps

Classified by use, pumps are called: Low Service, High Service, Deep Well, Booster, Sewage, Sludge, Boiler Feed, Chemical, Proportional Feeders, Air Blowers, etc.

Low service pumps operate at low discharge heads to lift water from sources of supply to water treatment works. High service pumps operate at high discharge heads to deliver water to distribution systems. Proportional feeders are used for dosage of solutions of chemicals or liquid chemicals; other uses listed are self-explanatory.

Selection of Pumps

Before a pump is selected for any use, it is desirable to be acquainted with pumping terminology and definitions. Such words as suction lift, discharge head, total dynamic head, specific speed, single stage, single suction, double suction, multiple-stage, split case, horizontal, vertical, and so forth are all important in the field of pumping.

In order to select a pump properly, it is necessary to have certain essential data on the pump installation. This information should include:

- Number of units required
- Nature of liquid
- Capacity
- Suction conditions
- Discharge conditions
- Total head
- Intermittent or continuous service
- Position of pump; horizontal or vertical
- Location, geographical, indoor, outdoor, elevation, etc.
- Type of power

Spacing of suction bells, methods of priming, size of suction and discharge pipes are other important factors in the selection and installation of pumps.

Pumping Station

Pumping stations or buildings to house pumps are usually necessary for both low and high service and booster pumps in water systems, as well as for sewage lift stations. Deep well pumps or motors may be housed or may not. Sewage sludge pumps are usually housed.

The architecture and surroundings of pumping stations of all kinds are generally designed to be attractive (both exterior and interior). This is in accord with the principles of good public relations to make the public conscious of the good service being rendered.

Operation

Reliability of performance, accessibility of service points and facility of repair are expected as is efficiency of operation regardless of the type of pump.

Some of the problems of pump operation include packing troubles, bearing troubles, misalignment, cavitation, water hammer, power failure, noisy operation, suction line losses, discharge line losses, clogged impellers, improper priming, air leaks into pump and others.

Regardless of the type of pump or the use, a preventive maintenance program and schedule should be set up in conjunction with its operation.

Centrifugal Pumps

by Paul C. Ziemke,
Clinton, Tenn.

Centrifugal pumps are those in which fluid is given an initial velocity and pressure by a rotating impeller. The action is not positive since the amount of fluid discharged is not necessarily proportional to the impeller displacement. The absence of valves and the packed pistons common to displacement pumps, makes them well adapted to handling dirty or gritty water. The fact that the moving parts have a rotary motion in place of a reciprocating motion makes them quite suitable for electric motor drives, either directly from the motor shaft in most instances, or by pulley and belt if the pump and motor speeds do not coincide. Compactness makes the pump well suited for confined areas.

Description

Centrifugals consist of: (1) A rotary impeller which draws in the fluid at its center and (2) a stationary casing in which the fluid is thrown from the ends of the impeller and is guided into the discharge outlet. An increase in the peripheral speed of the impeller increases the pump's effectiveness either through an increase in the pressure, or an increase in rate of discharge. The casing may be either cylindrical or concentric with an impeller of spiral form which may be plain or fitted with diffusion vanes. The pump may have any number of impellers. The shape of the impeller and the casing, and the number of impellers or stages determine the efficiency of the pump.

Advantages vs. Disadvantages

Some of the advantages of the centrifugal pump as compared to the plunger type are: (1) low first cost, (2) compactness, (3) absence of valves and pistons, (4) low rate of depreciation, (5) uniform pressure and flow of liquid, (6) simplicity of design and ease of operation, (7) freedom from shock injury through water hammer, (8) high rotating speed permitting direct connection to electric motors and steam turbines, (9) ability to handle dirty water, (10) pressures unable to increase beyond predetermined working values, and (11) ease of repair.

Some disadvantages are: (1) efficiency not as high as the best types of plunger pumps, (2) cannot be driven by slow speed engine, when high lifts are desired, and (3) the rate of flow cannot be regulated readily for wide ranges in duty.

Features of the Motorpump

The motorpump is a compact unit that requires a minimum of mounting space with the motor and pump mounted on a universal base. The impeller is precision balanced for maximum performance which assures good mechanical balance, and smooth, vibrationless operation. The hydraulic balance reduces the thrust and places suction rather than discharge pressure on the stuffing box. Its deep stuffing box provides space for up to five rings of packing and a sealing gland. The bronze needle valve in the stuffing box sealing allows pump discharge pressure to be adjusted for proper sealing and lubrication. In units where mechanical seals are used in place of packing, the needle valve is replaced with a throttling orifice.

The single unit pump and motor shaft are usually made of stainless steel to improve their resistance to wear and the effects of acids and alkalis. The hard shaft is durable but the machine has replaceable sleeves to compensate for eventual wear. Packing is provided between the sleeve and the impeller to prevent leaking under the shaft sleeve and subsequent corrosion at that point. The two piece packing gland of the split type is easily removed from the shaft, giving space for repacking as required. Ball bearings are provided for radial and thrust capacity. A cartridge type housing seals out the dust and dirt. A unique feature is a liquid flinger on the shaft that protects the motor bearings from contamination. The removable suction nozzle allows easy access to the impeller without disturbing the discharge piping. Replaceable casing rings seal the impellers.

THE MOTORPUMP is a compact unit requiring little space—An Ingersoll-Rand Co. pump.

The Volute Pump

The open-runner single inlet volute is the most commonly used for lifts up to 50 ft. Multistage pumps are employed for elevating liquids up to 80 ft. Pressure to lift the fluid is obtained by the conversion of a large part of the velocity head, produced by the impeller, to pressure head. The direction of the motion of the fluid at the instant it leaves the impeller is the resultant of motions tangential to the periphery of the impeller blades. The volute chamber is designed so that the cross-sectional area increases gradually toward the discharge pipe, and the change from velocity head to pressure head thus takes place with the smallest possible loss. The total head which the pump must equal, is the sum of the differ-

ence in head between the intake and the discharge levels, plus the velocity head required to give motion to the fluid, plus losses in the pump and losses due to friction in the pipe lines. The shape and curvature of the impeller blades are important considerations in design for any given service.

Impellers may have four, six or more blades. The shell may enclose replacement type liners or the shell itself may be designed to take the wear. Impellers and liners are generally made of cast iron or manganese steel; however, rubber liners and rubber cased impellers are standard features in many modern pumps designed for abrasive pulps.

The greatest wear is on the impellers and liners; it varies with the size density and abrasiveness of the entrained particles. Coarse material causes greater wear than fine, and very thick pulp cause less wear than those of intermediate densities.

Rubber lined pumps of different types and sizes are effective in a large group of installations. Pumps operated at the highest mechanical efficiency usually require the largest expense in replacement of linings. Wear is greatly accelerated by overloading and by excessive speeds. Experience has shown that deterioration of a rubber covered impeller is much more rapid than that of the case linings. Wear on uncovered white iron impellers is diminished by rubber linings of the case, probably due to the better stream lined flow obtainable in the absence of pits. The development of pits on metal liners is inevitable.

Pump's Metal Parts

The pumps are usually furnished in a variety of materials to suit the customers needs, depending on the liquid handled. Some of the special makes employ ni-resist, carbon steel, nodular iron and many types of stainless steel.

A few of the special types are listed here:

Pump Part	Liquid Pumped: Water	Mild Caustics — Hydrocarbons	Juices — mild acids
Chassis	Regular or bronze fitted cast iron	All iron	All bronze
Impeller	Bronze	Cast iron	Bronze
Casing	Cast Iron	Cast iron	Bronze
Casing rings	Bronze	Cast iron	Bronze
Shaft sleeve	Bronze	Mild steel	Bronze

Pump Installation

Specific Speeds

Specific speed is an index employed in determining a desirable rotative speed. Such desirable rotative speed may be 3500 rpm for a small capacity pump with low suction lift or it may be only 300 rpm for a larger pump with high suction lift.

Specific speed gives one a picture of the relationship between head, rotative speed and the capacity in gpm of any pump.

The formula is as follows:

$$\text{Specific speed} = \frac{\text{rpm}\sqrt{\text{gpm}}}{\text{H } ¾}$$

In as much as the application specifies the capacity in gpm and the head in feet, the engineer will make the above calculation in order to select a rpm which will give the desired specific speed.

If the suction is high, it is necessary to operate at a rpm which will give a low specific speed. Experience has shown that the high specific speeds may cause serious cavitation in pumps operating with suction lifts or even with small positive heads on the suction. Putting it another way, pumps with high specific speeds should be used only where the application is carefully engineered and maintained.

The efficiency of centrifugal pumps increases up to 2000 specific speed. Above this figure, little or no improvement in efficiency occurs. As the specific speeds rise above 6000 to 8000 there is a tendency toward reduction in efficiency which can only be offset by the most skillful and careful design.

In this connection, the design point of the pump is the point selected for the specific speed calculation.

The appropriate rough and ready classification of pumps is:

1. Low specific speed pumps.
2. Medium specific speed pumps.
3. Mixed flow pumps
4. Axial flow pumps.
5. Axial flow pumps of high specific speed.

Suction Lifts

The table indicates the approximate theoretical maximum suction lift in feet at 60°F for various altitudes and fluid densities; actual lifts ordinarily will not exceed one half the theoretical. Increase in temperature reduces the maximum suction lift, owing to the increased liberation of vapor at higher temperatures. Very hot liquids should be fed by gravity to the suction line.

Effects of Temperature on Suction Lifts

°F	Approx. Theoretical Max. Suction Lift at Sea Level
60	34
80	33
100	32
120	30
140	27
160	23
180	26
200	08

Pipe Layout

The pipe layout should be carefully planned; a level run may cause clogging, bends should be as few as possible and of long radius; valves should not be placed in pulp lines since closing may cause solid material to pack so that the line will not clear again when the valve is opened; stopping the pump may cause similar trouble. Provision of a by-pass to be opened just before shutting down the pump will maintain a clear line; shutting off supply pulp and substituting clear water before shutting down is also recommended. The by-pass is the best arrangement, as the pipes can be drained if the pump stops accidentally.

Velocities of 350 fpm in discharge pipes and 200 fpm in the suction line will, in general, prove satisfactory.

Suction Line

Keep the suction line free of air pockets; use a suction line at least one size larger than the pump nozzle. Arrange the length and size of suction so that the maximum suction lift, including all losses, will never exceed 20 ft of water (17.5 inches of mercury). When the pump operates with

The longest line of
PUBLIC WORKS EQUIPMENT

Vertical sewage pump

Centrifugal Pumps — Vertical or horizontal, for sewage and activated sludge.

Vertical Turbine Pumps — Wide range of sizes.

Blowers — For sewage aeration.

Rotary Vacuum Pumps—For use with vacuum filters in dewatering sludge.

Rotary Compressors — For compressing digester gas.

Dryers — For sludge dewatering.

Vibrating Screens — For removing solids from liquids; also in fertilizer manufacture.

Sifters — For grading fertilizer.

Roller Mills — For grinding fertilizer.

Motors and Control — For all drives over 1 hp.

Power Equipment — Steam turbines, condensers, pumps, water conditioning.

Electrical Equipment — Transformers, switchgear, circuit breakers, unit substations, generators, voltage regulators.

Engines — Diesel, gasoline and LP gas. Also generating sets.

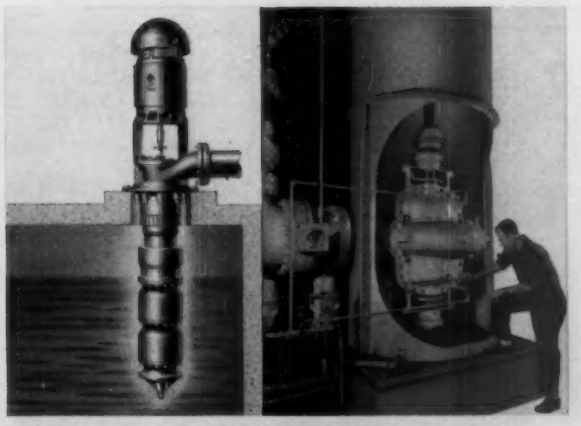
Tractors — Graders, earth moving equipment.

Lift Trucks — For quick and easy handling of materials.

Valves — Butterfly and rotary types for water and Sewage Works applications.

Here's a new motor development that can save you money. This open-type *Super-Seal* motor ran for hundreds of hours under water . . . in a 4% brine solution. If you have had trouble with ordinary open motors and are considering splash-proof or enclosed types get in touch with Allis-Chalmers and ask about *Super-Seal* motors.

The answer to all your needs



Vertical pumps are proving to be the answer to many waterworks problems . . . space . . . flooding. Allis-Chalmers offers a choice of pumps, depending upon application. Type S centrifugal pumps are used in many waterworks, both large and small. Vertical turbine pumps (right) are available for capacities up to 8000 gpm, heads to 400 ft or more.

There's good reason why Allis-Chalmers is recognized as *the* leader in the public works industry. Nowhere else in the world will you find the convenience of a single source for so much public works equipment.

One look at this long list reveals that Allis-Chalmers can help you solve any problem, whether your operation is a sewage plant, water works, municipal power plant, street and highway construction, or other projects.

Imagine a line of pump sizes ranging in capacities of a few gallons per minute to huge 300,000-gpm units. And what a reputation they have. Not one centrifugal pump has ever failed to meet its guaranteed efficiency.

Pumps are only a part of the extensive line of equipment manufactured by Allis-Chalmers. There are motors of every type for operating every size pump, and control for every motor. There is also every type of power generating and power distributing equipment helping municipalities all over the world to grow and prosper.

Allis-Chalmers will help you analyze your problem and select the proper equipment for your needs.

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Take advantage of Allis-Chalmers public works experience. Call your nearby A-C office, or write Allis-Chalmers, Milwaukee 1, Wisconsin

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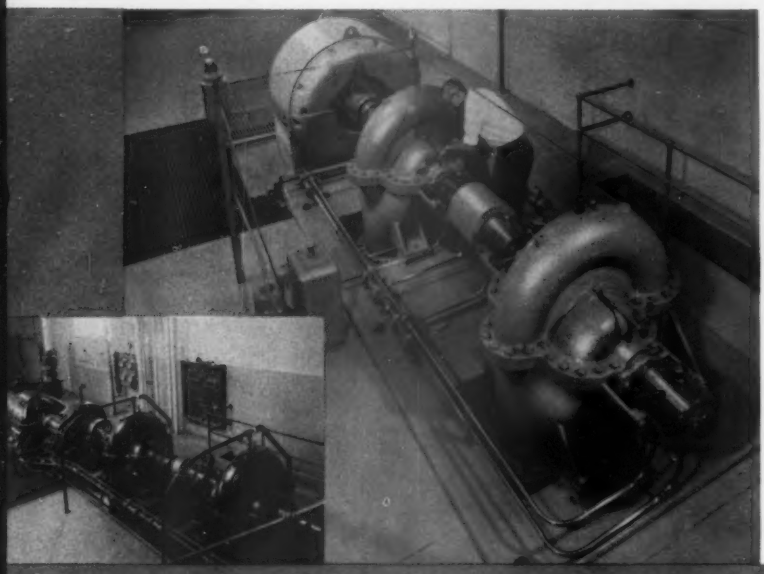
WATER WORKS EQUIPMENT....



Why you get MORE pump value when you specify Allis-Chalmers

You draw on Allis-Chalmers wide experience in supplying pumps for public works . . . for expert engineering and application help. You get pumps made of best-quality materials, of heavy duty construction, of high-efficiency design. Allis-Chalmers is the only company that offers you "one source" responsibility, with a complete unit—pump, motor and control—all built to work together—all built by A-C.

This installation in Harrisburg, Pa., shows one of the reasons so many municipalities choose Allis-Chalmers Type S pumps. The insert photo shows the installation as it was made in 1922. During the intervening years cost of purchased power has decreased in relation to other power costs and maintenance costs on the old turbines and boiler system greatly increased. *The pumps, however retained their efficiency and low maintenance.* Instead of buying new units, the drives only were changed . . . from steam turbines to Allis-Chalmers electric motors. They are now good for many more years of low cost operation.

Allis-Chalmers helps you . . .

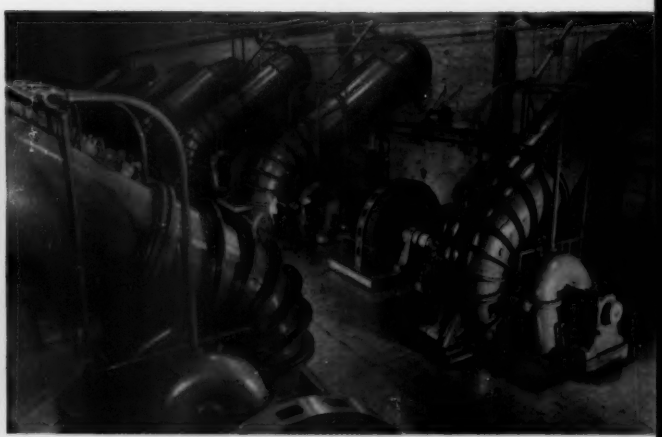
PUT WASTE TO WORK

Plan sewage disposal system to help pay for itself

Expansion is the goal of every progressive community, and with expansion comes rising costs in added sewage plant facilities and equipment. Allis-Chalmers experience in public works systems can help you with a profitable expansion or modernization program.

The sludge flow sheet shows the variety of Allis-Chalmers (shaded) equipment used to extract valuable by-products, and how many communities are applying them to cut plant operating costs. Some are finding the sale of fertilizer defrays as much as two-thirds the cost of plant operation. Digester gas is being used to supply power and light needs.

At the Metropolitan Sanitary District of Greater Chicago, West-Southwest sewage treatment plant, this 200,000 cfm, 8½ psig, four-stage axial is used as a base load machine. The centrifugals in the background provide the balance of the capacity needed, and meet load swings.

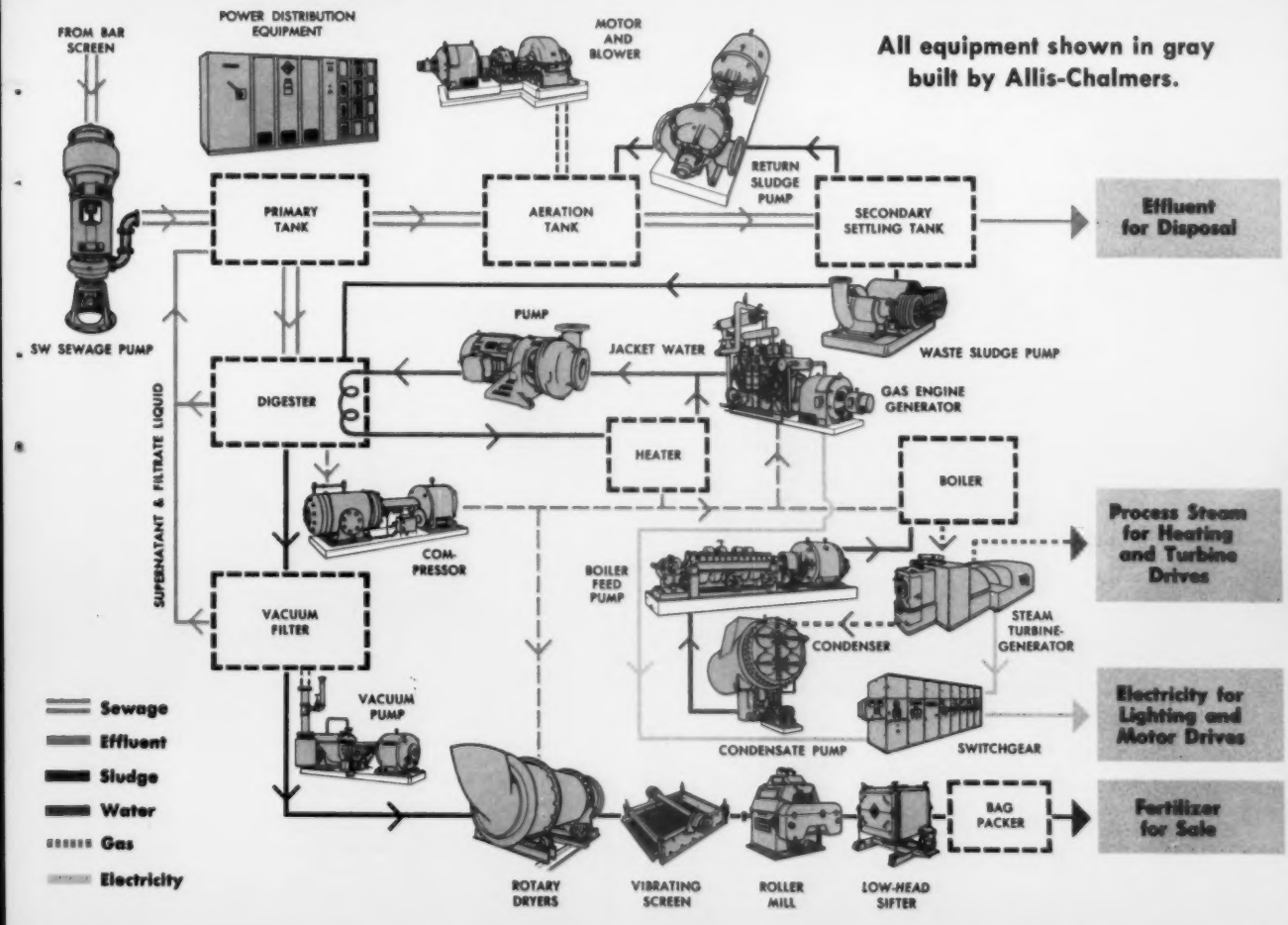


Twelve 72-inch centrifugal pumps at the Racine Ave. Station, Sanitary District of Chicago. They range in capacity from 375 to 500 cfs. They are driven by Allis-Chalmers synchronous motors, ranging in size from 1000 to 1750 hp.

City of Elyria, Ohio, uses four 12 x 10 inch Type S double suction pumps driven by Allis-Chalmers squirrel cage motors. Three are rated 3500 gpm and one at 2800 gpm, against 330 and 320 ft heads.

City of West Allis, Wis., pumping station is equipped with Allis-Chalmers vertical Type S pumps, *Roto-Valves* and rubber-seated butterfly valves.

Colorado River Municipal Water District station has five Type S pumps driven by Allis-Chalmers squirrel cage motors and controlled by the Allis-Chalmers metal-enclosed units shown on the right.



ELECTRIC POWER EQUIPMENT

• Generation
• Distribution
• Control

Allis-Chalmers can supply a major percentage of all power generation, and electrical control and distribution equipment for public works. Included in the power generation line are steam turbine-generator units, surface condensers, condenser and boiler feed pumps, water conditioning service and equipment.

The range of electrical products includes all types and sizes of motors from 1 to 100,000 hp and up, and control to suit every application.

Allis-Chalmers indoor and outdoor high and low voltage switchgear provides maximum protection and flexible control of power distribution circuits. All units are metal enclosed, factory built, so they need only be bolted in place and lines connected. Switchboards are custom built to fill your needs.

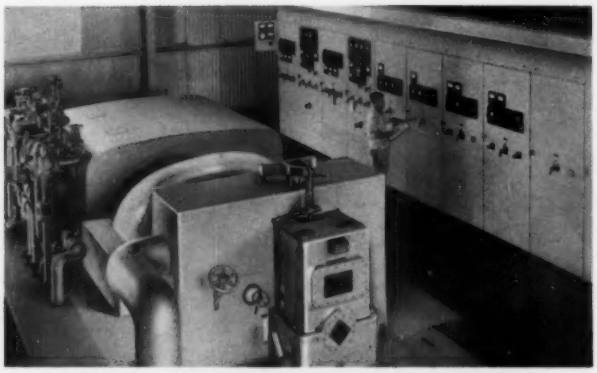
A-C builds a complete line of power and distribution transformers. Most sizes can be cooled with either oil or *Chlorextol* non-inflammable liquid, or they can be of the air-cooled type.

Load center, single circuit and multi-circuit unit substations are built in standard ratings to meet every application. They are completely factory built and can be installed adjacent to equipment being served.

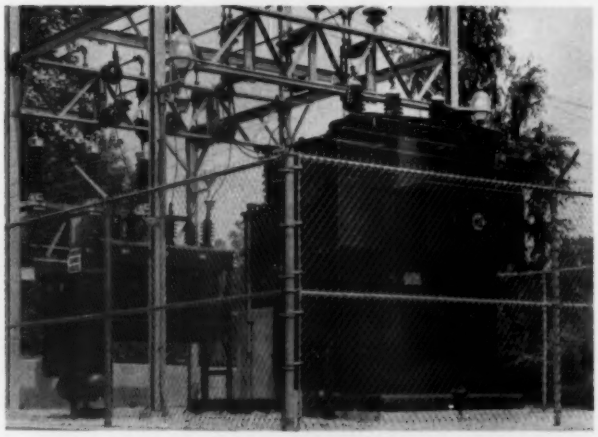
Allis-Chalmers manufactures a complete line of waterworks and sewage plant control, including low and high voltage equipment, dc control, and special control systems to meet specific needs.

Above are representative low-voltage across-the-line starters. At right is a 2300-volt, metal-enclosed starter with current limiting fuses. This starter can be supplied with either air or oil immersed contactor.

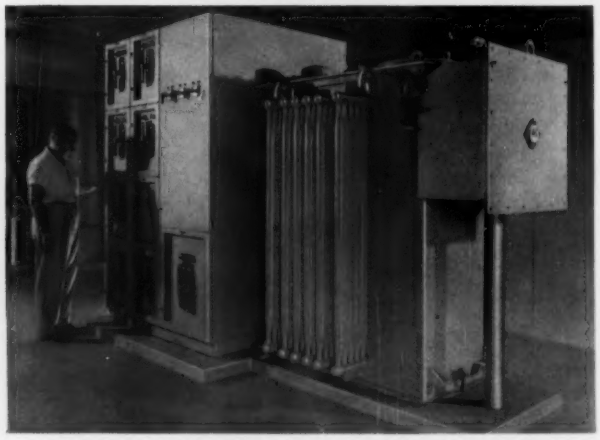
Chlorextol is an Allis-Chalmers trademark.



Allis-Chalmers 5000-kw, 3600-rpm WA-Series steam turbine-generator unit with Allis-Chalmers switchgear in background.



Allis-Chalmers out-door substation protects and controls the electrical power supply for a pumping station.



Load center unit substation in a Midwest plant. With this factory-assembled unit you get power right where you want it . . . without long runs of secondary wiring.

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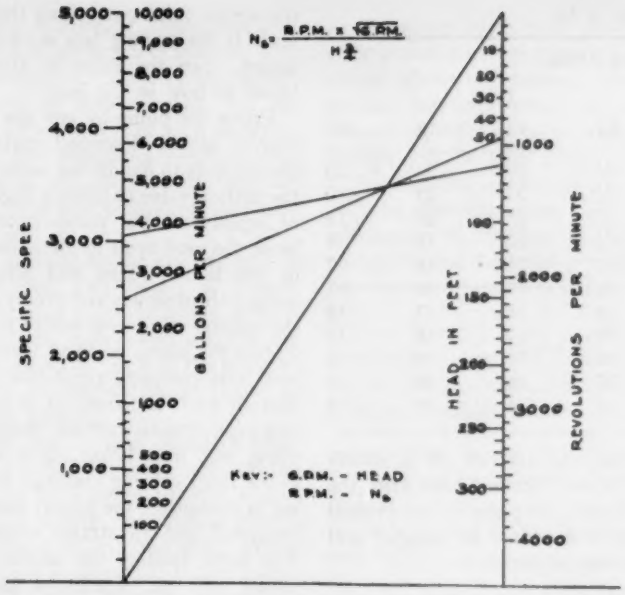
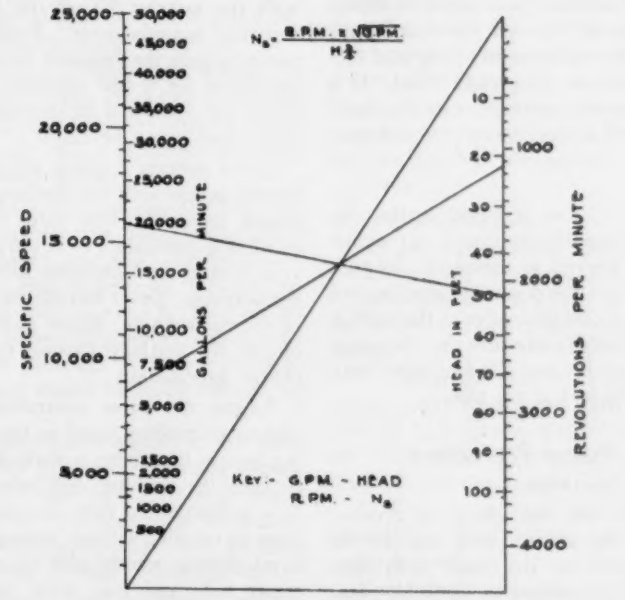
Take advantage of Allis-Chalmers public works experience. Call your nearby A-C office, or write Allis-Chalmers, Milwaukee 1, Wisconsin.

LITHO IN USA D&J-5



EXAMPLE: 2500 G.P.M. at 50 Foot Head at 1150 R.P.M. $N_s = 3060$.



EXAMPLE: 20,000 G.P.M. at 50 Foot Head at 1150 R.P.M. $N_s = 8650$.

a suction lift, the suction pipe should slope upward to the pump nozzle and downward toward the source of supply. Horizontal suction lines should have a gradual rise. Do not install any part or section of a suction higher than the pump suction nozzle.

Whenever another pipe or other obstruction requires bending from the natural slope, run the suction under the obstruction rather than over it. The pipe reducers at the pump suction nozzle should be of the eccentric type to prevent air pockets in the suction line. A gate-valve should not be used in the suction line under the suction lift; however, when used, air pockets can be eliminated by turning the valve stem in a horizontal or bottom direction. The end of the suction pipe should be at least 3 ft below the minimum pumping level of the liquid pumped. The pump must never be throttled on the suction side. After the installation check the line with water or pressure to make sure there are no leaks.

Foot Valve

The foot valve should not be installed in the suction if other means of priming are feasible. If the foot valve is deemed necessary it must be installed at the extremity of the suction and preferably below the mean water level. The foot valve should be of the wing type and should have a passage of at least 150 per cent of the suction area. Any small piece of debris caught in the foot valve will cause the pump casing to drain during idle periods, and then it will not pump again.

When a foot valve is used to prime a pump having an automatic start and stop control, by-pass line of ⅛ inch pipe should be installed around the check valve to the suction. A safety device must be installed to prevent the pump being started if not fully primed. For manually operated pumps a control valve in the by-pass will prove convenient to prime the pump and the suction before starting up.

The Strainer

To keep the pump from being clogged with foreign matter it is essential that a strainer be installed in the suction. To keep the pump from "starving" when partial blockade occurs it is required to have the strainer four times the area of the suction pipe. Bad conditions may require the installation of trash racks that can be cleaned at intervals.

The Discharge Pipe

Install a check valve and a gate valve in the discharge line. No manufacturer will make replacements at his expense if the pump is run without a check valve. When the pump is stopped, the check valve will protect the pump against excessive pressure and backward flow of the liquid in the discharge pipe. The check valve should be installed between the gate valve and the pump in order to permit inspection. The gate valve is frequently useful in starting and priming the pump.

Pump Priming

Liquid must fill all parts of the centrifugal pump before it can be started.

Maximum Suction Lift in Ft.

Altitude above sea level, ft	Specific Gravity of Fluid. 1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
Sea level	34	31	28	26	24	23	21	20
1,000	33	30	27	25	23	22	21	10
2,000	32	29	26	24	22	21	20	18
3,000	31	28	25	23	22	20	19	18
4,000	29	27	24	23	21	20	18	17
5,000	28	26	23	22	20	19	18	17
6,000	27	25	22	21	19	18	17	16
7,000	26	24	21	20	19	17	16	15
8,000	25	23	21	19	18	16	16	15
9,000	24	22	20	18	17	16	16	14
10,000	23	21	19	18	17	16	15	14

Many parts in the pump's construction are completely dependent on the flow of liquid to furnish the lubricating medium. To attempt to run a pump dry can develop disastrous results. There are five methods for priming pumps: (1) submerged suction, (2) ejector, (3) vacuum pump, (4) foot valve, and (5) sump service (automatic priming). Pumps, which have been installed so that their center-line is below the level of the liquid to be raised, will prime themselves automatically when the vent in the top of the casing is opened to release the entrapped air. A float controlled switch installed in the suction tank or sump will stop the unit in the event of liquid level failure. This will protect the pump from running dry and ruining the water lubricated bearings. Protective features are provided for automatic starting and stopping with provisions made to stall a pump if priming is not effected prior to start-up.

Pumps operating under a suction lift may be primed by means of an ejector or exhauster operated by compressed air, steam or water. The ejector must be installed at the highest point of the casing where a suitable tap is provided for that purpose. The ejector removes the air from the pump casing and suction line, and allows the water to rise to the level of the casing.

To prime the pump with an air or steam ejector or exhauster, close the gate valve in the discharge line near the pump (if the discharge pipe is full of liquid it is unnecessary to close the valve, because the check valve will be water sealed). Turn on the ejector. As soon as the waste pipe of the ejector throws liquid continuously, the pump may be started. If a steady stream is not obtained soon after the pump starts, the pump is not primed properly and should be stopped and the priming repeated.

Foot Valve Primers

With a foot valve installed and no liquid in the discharge, close the discharge valve and pour liquid by means of a funnel through the vent in the top of the casing until casing and suction line are completely filled. If a water supply under pressure is at hand connect it to the suction pipe and open the air cock on the casing to release the air.

Where there is liquid in the discharge pipe, the pump and suction line may be primed by means of a by-pass piped from the discharge pipe beyond the check and gate valve to the suction line. Always make sure that the pump is primed because the foot valve may develop a leak at any time.

Pump Protection

Pump Operation

Never run the pump in reverse. Check the arrow mark cast in the frame and run the motor with temporary connections to check for rotation and see that the motor name plate data checks with the speed indicated for the pump. Never use a series type direct current motor which will run wild when the pump is unloaded. Also when using a compound motor make sure the field is properly placed in the circuit and energized accordingly.

In starting pumps for the first time, and always when there is no pressure in the discharge line, close the gate valve in the discharge line. If the pump has a suction lift and the stuffing box is internally sealed, close the needle valve controlling the liquid seal. If the stuffing box is externally sealed, open the valve to allow the liquid to flow in the box.

Prime the pump by any one of the several means described earlier. If the pump is to handle hot water, open the suction valve to allow a slight flow of liquid into the pump casing and leave the vent open to allow overflow of the liquid. This will allow the pump to heat slowly and evenly. Open the suction valve wide before starting. Rotate the pump by hand through at least one complete revolution to see that all parts are free. It is possible that pipe strains, extreme rough handling, etc. may bring about contact of the rings causing binding. If binding is evidenced, the piping should be realigned and all strains eliminated. The bolts holding the suction pipe, casing and etc. should be loosened until the binding is freed.

After the pump is fully primed, close the starter switch in accordance with the instructions offered by the electrical manufacturer. Permit the pump to gain the required speed and let it run for a few minutes. Then check for abnormal temperatures of motor and pump bearings.

Never operate a pump for an extended period with the discharge line closed, unless the vent valve is open to allow a circulation of liquid to prevent heating and probable seizing of the bearings. Never throttle the pump on the suction side; rather reduce the output by partially closing the discharge gate valve.

Adjust the valve controlling the sealing or cooling liquid in the stuffing box so that there is slight leakage to keep the packing well lubricated. It is important to keep the gland as loose as possible without leaking since overtightness merely adds up electric meter bills and may burn out the motor.

When the sump is exposed to freezing temperatures care should be taken to prevent any liquid freezing within the pump when it is shut down. When the pump is idle, and there is a possibility of freezing, the pump should be drained by removing the pipe plugs in the bottom of the casing.

Packing and Stuffing Box

The packing in general should be the softest available on the market and adapted to the service on which

the pump is working. The types are: For general service, soft asbestos with soap lubricant. For liquids which must not be contaminated, soft asbestos with a lubricant such as petrolatum. For petroleum products, solvents and, etc., soft plastic packing in ring form with addition of insoluble grease seal.

The packing in the stuffing box is divided into two parts: a lantern gland is used to guide liquid around the shaft to either seal off the air leakage along the shaft to the impeller inlet, or for circulation of liquid to cool the packing.

When the lantern gland is connected to the discharge side of the pump, as by a cored passage within the pump casing, the stuffing box is said to have an "internal seal." When the lantern is connected to the source of supply other than the pump discharge, the box is said to have an "external seal."

Pumps handling hot liquids are usually sealed with clear, cool liquid for cooling the packing.

Pumps handling dirty, gritty, or corrosive liquids should be externally sealed with clean, noncorrosive liquid to prevent rapid corrosion and scoring of the shaft sleeve.

When adjusting the stuffing box gland, tighten the nuts evenly while the pump is running. Always allow a slight leak to lubricate the packing and the shaft sleeve. A gland pulled up too tight will cause excessive wear on the packing. A gland properly tightened should be freely rotated by hand.

Metallic packing should be used only with hardened shafts and sleeves and when there is no grit or sediment present in the liquid. It is usually more satisfactory than soft packing for severe service. Particular attention must be given to metallic packing to prevent excessive wear between packing and the shaft sleeve.

Proper Lubrication

The life of any bearing is dependent on the care the bearing is given. First consideration is the selection of the proper grade of lubricant and that it is kept free of all contaminants while in storage or application. Additives such as graphite, resin and other foreign materials are warned against. DON'T OVER LUBRICATE. Excessive use of the grease gun readily do more harm than good since often grease seals are ruptured, grease forced where not desired, and overgreased bearings forced to run hot because of the congestion around the fittings and the relief plug.

Wipe clean the pressure gun fitting and the pressure fitting. The fitting will usually be found at the top of the end shield and the relief plug is at the bottom plug in the ballbearing cup, and adjacent to the shaft. On the face type end shield a relief plug opening is also provided at the bottom of the end shield, but is preferable to use the relief plug in the bearing cup because it opens directly into the grease chamber. The method: Remove the relief from the cup. With a sharp instrument remove any obstruction in the relief hole. Add grease with the hand gun with the pump running until grease is forced through the relief hole. When clean, new grease appears stop pumping the gun and permit the pump to run until all surplus grease has been expended.

Grease Specifications

The purchasing department should never shop for "bargains" but should be guided by the standards set up by the American Society for Testing Materials.

1. The grease must be sodium soap grease, carrying not less than 82 per cent of high grade, filtered mineral oil of Saybolt viscosity of not less than 150 seconds at 100°F.
2. The grease must not separate on standing or when heated below the melting point.
3. It must not gum or become sticky.
4. It must not decompose or harden.
5. It must not corrode any type of ball-bearing.
6. It must be free from resin, mineral salts, abrasive such as sand, free lime, etc.
7. It must have a melting point of not less than 300°F and a penetration at 77°F to 275 to 330.

Oil Lubrication Specifications

For all pumps having lubrication by oil, the following specifications are suggested for the procurement of the proper grade of oil.

1. The oil must be refined petroleum oil, free from all acids, alkalies, soaps, thickeners, or other non-petroleum substances which tend to make it emulsify, gum or "liver-up."
2. The oil shall conform to the following standard physical characteristics based on tests by the ASTM.

	Naphta Base	*Paraffin Base*
Flash Point	330°F Min.	360°F Min.
Saybolt Visc. at 100°F	150 Min. 200 Max. Sec.	150 Min. 185 Max. Sec.
Pour Point	5°F Max.	36°F Max.
Steam Emulsion Value	75 Sec. Max.	75 Sec. Max.

Annual Checks

Perhaps one of the most severe duties imposed on a centrifugal pump is that of boiler feed service where a look inside once a year is suggested to learn if wear, fractures, poor circulation, cavitation or over-heating are causing bad performance. In the stuffing box look for wear from the packing or corrosion set up by the material handled. Check for corrosion set up by the material at the ends of the sleeves. See that the water finger ring is tight on the shaft, seal with paste if needed. On the small type bearing insert four or five turns of wire solder, then fasten down the bearing cap. Then "mike" the strands produced to learn where to remove shim stock to take up wear. On shell type bearings make a bridge gauge reading to determine wear on the lower half of the bearing. A feeler gauge will be needed to check between gauge and shaft. Babbit for all spots of wear. Look the impellers over carefully to note the wear at the rings and check vanes. Erosion, corrosion and cavitation raise hob at eye and discharge vanes.

Check the key securing the impeller to the shaft. Perhaps it can be driven home, or must be replaced with a larger one; or key ways must be recut to take a larger key. See that the clearance between impeller and casing wearing rings match up to design specifications. Pump performance falls off badly if the clearance of 0.003 inch is exceeded. Don't let the opening double the factory established clearance. The thrust bearing clearance can be checked by separating the shaft coupling and measuring the shaft movement from each side of the impeller, near the tips and housing.

Field Testing of Centrifugal Pumps

by FRED W. BELTZ, JR.
De Laval Stream Turbine Co., Trenton, N. J.

The modern centrifugal pump has undergone a progressive development, until today it is one of the most efficient pieces of mechanical equipment in use. For more than 50 years, centrifugal pump manufacturers have developed the performance of these units by continued improvements in design and manufacture. Along with these improvements, there has been a continuous program of performance testing to analyze each improvement in design or manufacture. This performance testing has assured the user that the pump will meet the hydraulic conditions of his particular installation.

Nevertheless, no matter how good the performance is in the manufacturer's tests, the permanent installation is the final testing ground. This article gives details of field testing with a limited amount of instruments and simple calculations. These tests are sufficiently accurate to assure the operator that all the requirements of the installation are met.

Reasons for Field Testing

There are a number of reasons for field testing centrifugal pumps. Such tests show the exact operating conditions of the pump compared to purchase conditions. They check the accuracy of the head and capacity estimate, the motor sizes, the piping and valve size estimate, and the system head curve calculation. If field tests indicate errors in any of these areas it is often possible to correct the condition, sometimes before the unit is put "on the line."

Field testing also allows the engineer to obtain an accurate picture of his operating costs. The tests give him the exact power requirements of his individual unit, or several units in series or parallel operation. From these figures, he can obtain the most economical operation pattern, with subsequent savings in power and fuel. These savings are especially possible in installations containing large pumps and in systems having high-pressure discharge reservoir or standpipe capacity. Field testing will often point out the most economical step when additions for a system are planned.

Field testing also allows the plant engineer to evaluate operating conditions over the years. He can compare the sustained efficiency of various types of equipment in his plant to determine the actual cost of equipment above the original cost. This information is particularly valuable when additions or alterations are planned for an existing system or plant.

Perhaps the most unique and useful purpose of field testing is its use as a maintenance tool. It allows the plant engineer to "look inside" his pump without interrupting its operation and without down time or labor expense.

The performance of a pump is the best guide known to determine the need for renewing impeller or case rings, or, in multi-stage pumps, renewing interstage and breakdown bushings. Comparative performance of a pump over the years is a better guide to its condition than internal inspection and clearance measurements. Careful observation of test results has allowed many plant engineers to keep units on the line for five or six years without overhaul, an obvious improvement over the older practice of annual or semi-annual inspections.

Field tests are also frequently used for large waterworks pumps that are sold on a penalty-bonus contract that contains provisions for these tests. On the basis of these tests, a bonus may be awarded or a penalty charged to the builder of the pumps, depending on whether the unit exceeds, meets, or fails to meet the performance guarantees. Contracts of this type may carry evaluations as high as $10,000 per point of efficiency. Tests, of course, must be run under very exacting conditions, with all possible errors eliminated, and with all variables corrected. Although this article does not attempt to describe the details of these tests, the basic principles are no different from the tests described here.

Planning the Test

A complete understanding of the problem, plus careful planning and testing, is the secret of getting valid test results with a minimum of plant interruption and work. Before any testing can be done, the instruments to be used should be selected and calibrated, and the necessary taps and connections made. Meanwhile, data sheets should be prepared, with spaces for entering all necessary data and notes.

A little foresight here will prevent the omission of necessary notations, such as how or where a certain gage was connected. At the same time, the approximate flow increments should be selected, and the meter readings required to make this flow should be calculated. These approximate points will be used in the test to set the test point, giving good distribution of data over the full range, rather than just a group of points. The tests must be carefully planned to permit operation over the full ranges without disrupting plant operations. Of course, there is often no difficulty, but at other times testing must be synchronized with other plans.

Running the Test

Not until after all instrumentation has been checked out and everyone is familiar with the requirements, should testing begin. Normally the first test point is set at the highest capacity, lowest head point. If the flow is not constant because of changes in the system head, a person on the discharge valve should adjust it to maintain the desired flow. If readings are steady, one set is normally sufficient. However, if there is any appreciable change, four or five sets of readings must be taken and averaged.

The subsequent test points are set by adjusting the flow with the discharge valve until zero flow is reached. The zero flow point often will not be required. When it is, the unit should be held at zero flow or shutoff only momentarily for a spot reading, and then opened up again.

Often it may be difficult to get the head low enough for the high capacity points. If pumping into a standpipe, the level should be worked down to a minimum before the test, or the unit should be isolated from the system and the water discharged to a low-pressure point. Low-head pumps can be tested in a closed loop with very satisfactory results where the loop is of sufficient volume to control the turbulence.

It is usually possible to make a rough calculation of the data while the test is in progress. This method is recommended as the best means of spotting bad data or faulty instruments before the test is complete and the unit instrumentation is removed. In no case should the instrumentation be removed before there is a satisfactory quick calculation of the results on the data obtained. All the calculations can be performed with sufficient accuracy and speed on a 10-inch slide rule.

Measurement of Test Data

The performance of a centrifugal pump is a function of four or five basic variables. This is developed in some detail later; for the moment, however, let them just be recognized and then consider how to go about measuring them. Basically they are the flow or quantity of liquid being pumped, the head or pressure rise across the pump, and the power input to the pump. If the temperature of the liquid varies substantially the specific gravity is also a variable; if the speed of the pump varies, the speed will also become a variable. The simplest example will be the cold water pump driven by a constant-speed motor; the more complex will be a hot water pump operating over a range of temperatures and speeds.

Flow

Perhaps the easiest thing to measure, where proper permanent instruments are installed, is flow. Without these instruments, it often becomes the most challenging quantity to determine. There are many means of measuring liquid flow, most of them accurate enough if the necessary care is taken in the readings, corrections, and calculations.

Permanent instrumentation in the form of flow meters or recorders is no guarantee of accuracy. If the meter is of the Venturi or nozzle type, it must be free of foreign matter, tubercles, and erosion. The instrument lines must be purged of air bubbles. The register or recorder must be properly zeroed and calibrated by disconnecting the lines to the meter and checking the register against a water or mercury manometer. The instruction books for most commercial meters carry full instructions for their field calibration.

If there is no permanent instrumentation available, a study of the system will usually reveal one or more ways to measure the flow. Here the engineer must use his ingenuity and experience to decide the most practical approach for his particular plant. Some of the means available to determine flow are as follows:

1. Often there is a tank on either the high- or low-pressure side of the system. This tank may be in the form of a reservoir, standpipe, settling basin, filter bed, or a temporary tank installed for test purposes. To measure the flow, there must be provision for isolating the tank from the rest of the system, so that only the test water can flow in or out. Then it is only necessary to calculate the surface area of the tank and set up a vertical scale to measure the rise or fall.

If the vertical increments are small, a hook-type gage should be used as an index, which brings the point up from under the surface to minimize the effect of the miniscus. A formula

$$Q = \frac{448.8\,A\,Z}{T} \qquad (1)$$

can then be set up for the installation. Unless otherwise noted, all units in the formulas of this series are defined as given in Table 1.

2. Flow also can be measured very accurately by means of a tank on a platform scale. This method is often the easiest way to measure the flow of small capacity pumps. It is frequently possible to pipe the discharge with a temporary pipe or hose to an open tank set on a large platform scale. There must be provision for dumping the water to either a sump or a sewer, and there must be no mechanical connections between the pipe or hose and the tank on the platform scale.

The suggested timing procedure is to adjust the flow before starting the water into the tank, or before closing the dump valve on the tank. The beam scale is set so that the beam is down. The flow is started into the tank and then as the beam rises to the midpoint, the stopwatch is started. A suitable weight is then added to the beam, dropping it again. When the beam again rises to the midpoint the stopwatch is stopped. The flow can then be calculated from

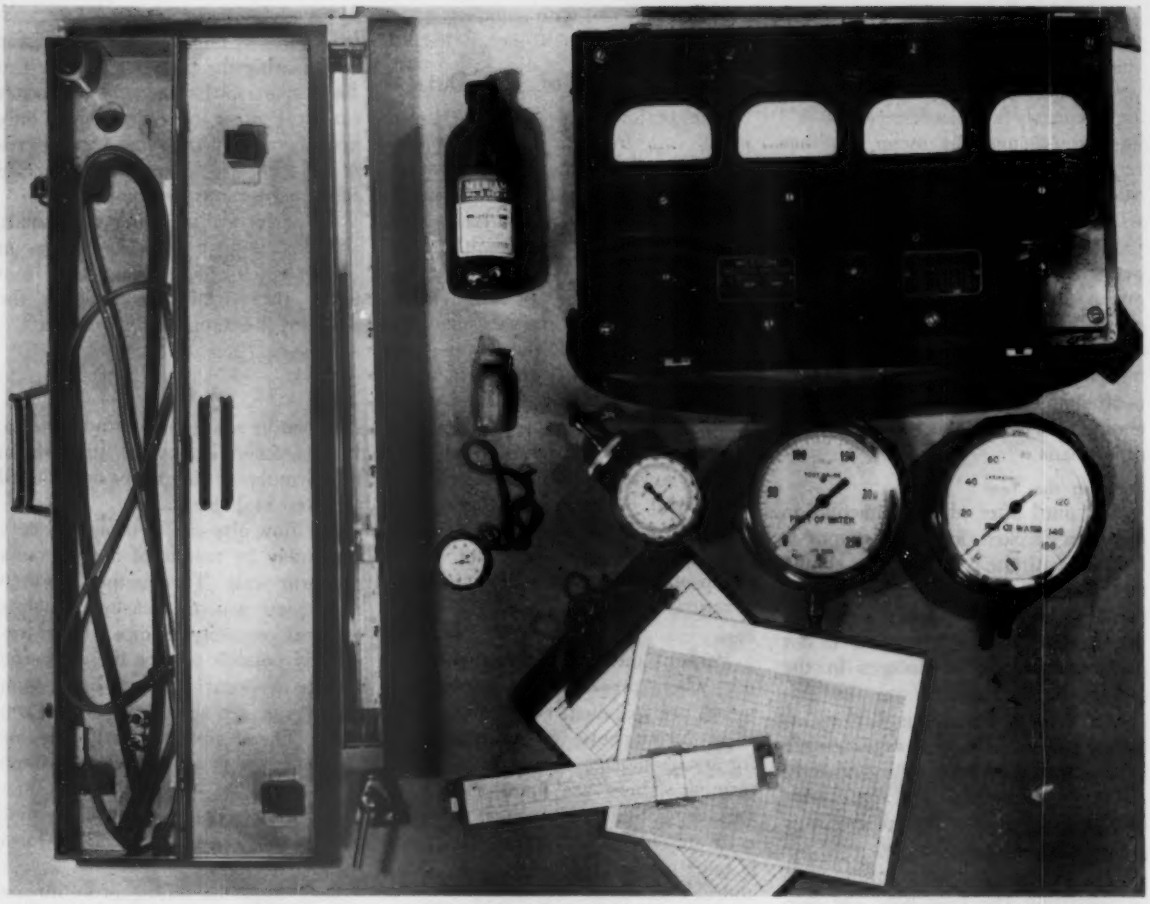
$$Q = \frac{7.2\,W}{T} \qquad (2a)$$

which is correct for water under 100 F. It requires correction to

$$Q = \frac{7.2\,W}{T\,S} \qquad (2b)$$

for specific gravity when hot water is handled.

3. The flow also can be measured by flow meters. Often a plant cannot justify permanent installatiin of a flow meter on each pump, but where there are a number of pumps of similar capacity, provision can be made for temporary installation of a meter for pe-



TESTING APPARATUS required, including (right to left): industrial electrical analyzer; pressure gages; clipboard with data and graph paper; slide rule; tachometer and stopwatch; manometer fluid and mercury; and a Merriam portable manometer.

riodic testing. When this type of set-up is planned, precautions must be taken to provide a sufficient straight run of pipe preceding the meter. Either the manufacturer's recommendation or various test codes should be followed. When the meter is used, it must be properly calibrated and the connections purged of air.

Orifice, nozzle, and Venturi meters usually are of the permanent type, but they often may be installed temporarily for test purposes. These types of meters are all based on the same principle—the restriction of the flow area, with a resulting increase in flow velocity. The change in velocity results in a difference in static pressure. The difference can be measured with a U-tube manometer filled either with mercury or one of the middle-range fluids (such as carbon tetrachloride or acetylene tetrabromide), or it can be measured with a differential-type pressure gage (such as the Bourdon gage).

These three types of meters (orifice, nozzle, and Venturi) have been the subject of extensive experiments and many technical papers, which often tend to confuse the engineer seeking a practical approach to problems in flow measurement.

However, the underlying theory is the same for all instruments and the flow of any of these instruments can be expressed by a general formula such as

$$\frac{KCD_t^2\sqrt{2gh}}{\sqrt{1-\left(\frac{D_t}{D_i}\right)^4}} \qquad (3a)$$

Eq. 3*a* can be simplified in terms of standard units using mercury as a manometer fluid and rewritten in the form

$$\frac{20.11\,CD_t^2}{\sqrt{1-\left(\frac{D_t}{D_i}\right)^4}}\sqrt{\frac{h_{hg}}{S}} \qquad (3b)$$

for cold water or for liquid of any specific gravity.

Eqs. 3*a* and 3*b* each contain the term C, the flow coefficient of the water, which can be obtained from the manufacturer, from calibration tests, or from "Fluid Meters," published by the American Society of Mechanical Engineers. This last publication is a complete treatise covering the subject from both the theoretical and practical viewpoints.

The value of C will normally be constant over the range that any instrument is used. Therefore, with the physical dimensions of the meter remaining constant, Eqs. 3*a* and 3*b* can be simplified to

$$Q = K_m \sqrt{h_{hg}} \qquad (3c)$$

where K_m is the constant for the particular meter and measuring instrument.

In the typical test, for example, a Venturi of 16.16-in. diameter inlet by

TABLE 1

Letter Symbols Used Throughout This Paper*

Symbol	Term	Unit Dimension	Symbol	Term	Unit Dimension
A	Area	square feet	P_g	Pressure gage reading	psig
bhp	Pump power input	horsepower	p_{hg}	Vacuum gage reading	inches of Hg
C	Flow coefficient	dimensionless	Q	Capacity of pump	gal per minute
D	Diameter	inches	S	Specific gravity of liquid	dimensionless
E	Over-all efficiency	percent	T	Time	seconds
E_g	Driver efficiency	percent	W	Weight	pounds
E_p	Pump efficiency	percent	w	Specific weight of liquid pumped	lb per cut ft
g	Gravitational acceleration	ft per sec per sec	w_g	Specific weight of manometer indicating liquid	lb per cut ft
H	Pump total head	ft of liquid	whp	Useful pump output	horsepower
h	Meter head	ft of liquid	Z	Elevation of measuring point above datum (negative if below datum)	feet
h_d	Discharge head	ft of liquid	Z_s	Elevation of suction measuring point above datum (negative if below datum)	feet
h_g	Liquid column or manometer reading	ft of liquid	Z_d	Elevation of discharge measuring point above datum (negative if below datum)	feet
h_s	Inlet or suction head	ft of liquid			
h_v	Velocity head	ft of liquid			
h_{hg}	Mercury column reading	inches of Hg			
n	Speed of rotation	rpm			
N	Number of turns	dimensionless			
p	Pressure intensity	psi			

* Unfortunately there is no agreement between the various test codes on the symbols and dimensions. Although an attempt has been made to follow the consensus of these publications, the meanings of the symbols, and particularly their units, must be checked when using the individual publications.

11.00-in. throat diameter was used. The water temperature was 67 F., so it was considered cold. The Venturi differential was read in inches of mercury. The meter constant, C, for this meter was 0.985. Therefore, the constant became

$$Q = \frac{20.11\, C\, D_t^2}{\sqrt{1 - \left(\frac{D_t}{D_i}\right)^4}} \sqrt{h_{hg}}$$

$$= \frac{20.11 \times 0.985 \times 11.00^2}{\sqrt{1 - \left(\frac{11.00}{16.16}\right)^4}} \sqrt{h_{hg}}$$

$$= 2707 \sqrt{h_{hg}} \qquad (4)$$

Thus, the calculation of the actual test points involves only measuring the deflection in inches, entering it on the slide rule, and reading off the flow in gallons per minute.

A typical readily available flow nozzle is the fire nozzle. This nozzle must be of the "smooth-cone" or "smooth-convex-cone" variety. By mounting such a nozzle on a length of pipe with a pressure tap preceding the nozzle, the nozzle can be used quite accurately. The formula for any smooth fire nozzle is

$$Q = 29.0\, D_n^2 \sqrt{P_g} \qquad (5)$$

in which Q is flow in gallons per minute, D_n is the diameter of the nozzle in inches, and P_g is the pressure preceding the nozzle in pounds per square inch.

4. Wiers also are an acceptable method of measuring flow and are particularly applicable where the water is pumped into an open culvert or irrigation ditch. The use of wiers, however, is a complete subject in itself, and the reader is referred to any good mechanical or hydraulic handbook.

5. Pitot tubes have been used successfully to measure the flow through pipes, but they are impractical for most pump testing installations. A considerable amount of precise work is required in making each flow traverse, and the flow must be maintained at a constant rate.

Pressure

Measurement of pressure is the next consideration. Water pressures are commonly measured with either Bourdon tube gages or U-tube manometers. The Bourdon tube gage is suitable for any normal pressure ranges. For accurate test work, however, a manometer is usually used for pressures less than 10 psi, and often up to 20 and 30 psi. For pressures less than atmospheric, a manometer is preferred.

All pressures require correction to a common datum plane, usually the horizontal centerline of the pump. If the instruments are portable, mounting the gages at the datum line or some other common line will often cancel out the elevation correction and eliminate extra calculations.

With manometers, there is normally no correction required in the gage itself. However, Bourdon tube gages should be calibrated before the test, or test gages of known accuracy should be used. Permanent mounted gages are not necessarily accurate for test purposes unless they have been calibrated prior to the test.

Two gage connections are required; one at the suction, the other at the discharge. The taps should be made either at the pump flanges or adjacent to them. The tap hole should be at least a drilled ⅛-in. hole to the water passage, and it should be free from burrs. Normally the gages are connected with flexible tubing and must be provided with vent cocks adjacent to the gage.

The most common U-tube manometer uses mercury as the balancing fluid. If the pressure being measured is less than atmospheric, the manometer should always be vented prior to the reading to insure a dry line. The top of the mercury should be free from water or foreign matter. The manometer can be read in inches and converted to feet of head by

$$h = \frac{h_g\, W_g}{62.3} \qquad (6a)$$

or for mercury and cold water,

$$h = 1.131\, h_{hg} \qquad (6b)$$

To this value must be added the distance between the tap and the datum line. The total will be the static suction lift in feet of water. If the tap is

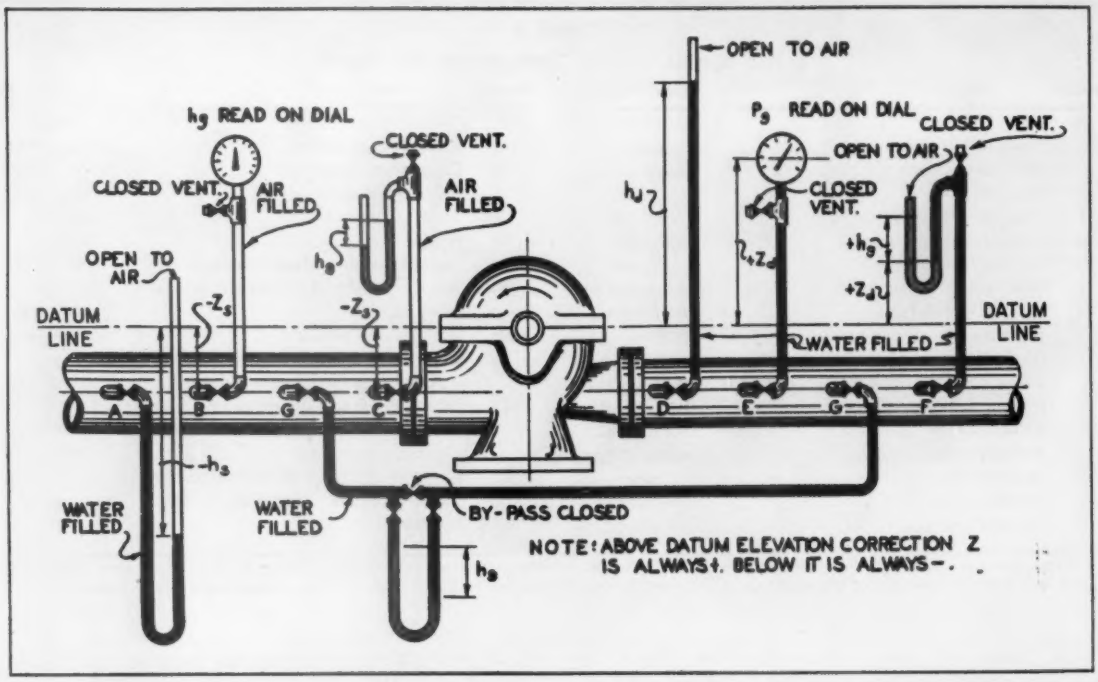


FIG. 1.—VARIOUS MEANS of measuring suction and discharge pressure on a centrifugal pump and how the corrections are measured to the datum line. The suction pressures shown are negative or less than atmospheric; if they were positive, they would be measured the same as the dicharge pressures, with the same elevation corrections. In each case elevations are measured in feet.

A. Suction pressure less than atmospheric measured with a waterfilled manometer. Distance minus h_s, in feet, is the suction head in feet of water corrected to the datum line.

B. Using Bourdon-tube vacuum gage with air-filled line to measure suction pressure. If gage reads in inches of mercury,

$$h_s = (-1.131\ h_g) - Z_s$$

C. Using mercury manometer with air-filled line to measure suction pressure. Deflection of mercury read in inches.

$$h_s = (-1.131\ h_g) - Z_s$$

D. Using water column to measure discharge pressure. Distance h_d, in feet, is the discharge head in feet of water corrected to the datum line.

E. Using pressure gage reading in psi, with water-filled gage line to measure discharge pressure.

$$h_d = (2.311\ p_d) + Z_d$$

F. Using mercury manometer with water-filled line to measure discharge pressure. Deflection of mercury read in inches.

$$h_d = (1.09\ h_g) + Z_d$$

in which

$$\frac{13.65 - 0.5}{12} = 1.09$$

G. Using mercury manometer to measure net pressure increase across a pump. All lines filled with water and deflection read in inches of mercury.

$$h_d - h_s = 1.048\ h_g$$

above the datum line, the distance is subtracted. When the suction is positive the most convenient practice is to allow the gage line to fill with water and to fill the connected side of the manometer on top of the mercury. Eqs. 6*a* and 6*b* are used to convert the manometer reading to feet of head. However, the elevation correction must now be made from the point where the water joins the mercury to the datum line. If this point is above the datum, the correction is positive; if below, the correction is negative.

Perhaps one of the simplest, and certainly the most accurate means of measuring relatively low differences in water pressure is with a water manometer. An instrument sufficient for testing, although hardly suited for a permanent installation, can be made from transparent plastic hose. If the pressure is positive, the hose is attached to the pipeline at one end and the other is left open to the atmosphere and supported above the tap. The vertical distance in feet from the water level in the hose to the datum line will be the head in feet of water, with no corrections or calculations necessary.

If the pressure is less than atmospheric, the line can often be dropped down to form a U-shape from the tap. The other end is open to the atmosphere and the tap side is purged of all air. The vertical distance in feet from the water level up to the datum line will be the head in feet of water, this time negative.

It is almost always necessary to provide some snubbing of the gage to dampen out slight line and gage pulsations. Generally, for test work the commercial gage snubbers are not used. Instead, it is more satisfactory to use a small valve or cock, manually adjusted. This action allows the use of a minimum amount of restriction and, at the same time, keeps the gage "alive."

Power

Equally as important as the waterpower output of a pump is the power input, whether it be in the form of kilowatts to a motor, fuel to an engine, or steam to a turbine. The quantities of fuel can be measured, and although often the breakdown cannot be made between losses in the driver and in the pump, the over-all efficiency of the driver and the pump, often referred to as the "duty," can be analyzed. This unit is important to the operator because it reveals the exact cost of operation.

Motors, certainly the most common drives of centrifugal pumps today, lend themselves well to testing. The

power input is easily measured with a voltmeter, ammeter, and powerfactor meter. For an AC three-phase motor the formula is

$$kw = \frac{1.732\, v\, a\, pf}{1{,}000} \quad \text{.....(7)}$$

An effective alternate way to measure motor power input is to use a watt-hour meter and time the disk with a stopwatch, the power is calculated from

$$kw = \frac{n}{T} \times \frac{3{,}600}{1{,}000} \times K_h \quad \text{.....(8a)}$$

or

$$kw = \frac{n}{T} \times \frac{3{,}600}{1{,}000} \times K_h \times \text{PT} \times \text{CT} \quad \text{(8b)}$$

in which n is the number of revolutions, T is the time, K_h is stamped on the meter face, PT is the potential transformer rating, and CT is the current transformer rating.

Even where there are no normal means provided to measure the power input to a motor, the job often can be done with surprisingly little effort. A very useful instrument, remarkably accurate, is the "clamp-on" type of ammeter. Another portable instrument, available in almost every plant or which can be borrowed from the local electric company, is the industrial test analyzed with a voltmeter, ammeter, powerfactor meter, and wattmeter built into a single case with the necessary transformers and connections built in.

After the power input is measured, the next step is measuring the power output. Of course, this is a function of the motor efficiency:

$$\text{bhp}_{\text{output}} = \text{bhp}_{\text{input}} \times E_m \quad \text{.....(9)}$$

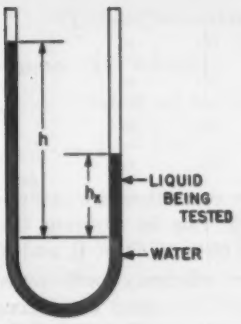
in which

$$\text{bhp}_{\text{input}} = \text{kw}_{\text{input}} \times 1.341 \quad \text{.....(10)}$$

and E_m is the motor efficiency.

The motor efficiency can be obtained accurately from elaborate tests of the motor losses, but normally this is not required because the motor manufacturers can supply the guaranteed motor efficiencies. The best data available should be used for the most accurate results.

Engines, both diesel and gasoline, drive a great number of centrifugal pumps. Although the fuel consumption can be measured easily, it normally is difficult to calculate the horsepower output with any degree of accuracy. However, by measuring fuel consumption carefully with the engine under approximately rated air-inlet conditions, the operator can obtain the information he needs: fuel consumption *vs* pump output. Here the individual test requirements will dictate the necessary data and how the results are plotted.



NOTE:

MEASUREMENTS MUST BE EXACTLY VERTICAL

FIG. 2.—CHECKING specific weight of a manometer fluid, such as carbon tetrachloride or acetylene tetrabromide.

$$\frac{h}{h_x} = \frac{w_x}{w} S_x, \text{ or } w_x = \frac{w\, h}{h_x}$$

where h_x is the head of the liquid being tested and S_x is the specific gravity of the test liquid.

Example: Water at 68F, $h = 17.05$, $h_x = 7.75$

$$w_x = \frac{62.32 \times 17.05}{7.75} = 137.1 \text{ lb/cu ft}$$

$$S_x = \frac{17.05}{7.75} = 2.20$$

Specific Weights and Specific Gravities of Common Manometer Fluids

Fluid	Spec. Wt.	Spec. Gr.
Mercury	845.90	13.546
Water, 68 F	62.32	1.000
CCl_4	99.40	1.594
$CHBr_4$ $CHBr_2$	184.70	2.964

Carbon tetrachloride (CCl_4) and acetylene tetrabromide ($CHBr_4$ $CHBr_2$) should be tinted with either a pinch of iodine crystal or with one of the dyes available from instrument suppliers. The specific weight should be checked occasionally, rather than relying on the foregoing values.

Steam turbines are used for many pump drive applications. As with the engine, it is difficult to measure the power output in terms of brake horsepower. However, in today's modern power plants, the use of steam or condensate flow meters is becoming increasingly popular, and, although they do not allow measurement of horsepower output of the turbine, they do permit analysis of the "duty" of the unit, or its performance in pounds of steam per foot-pound of work. This often is expressed as:

$$\text{Duty} = \frac{W\, H}{W_s} \times 1{,}000 \quad \text{.....(11)}$$

On which duty is for 1,000 lb of steam, W is the pounds of water pumped per hour, H is the total dynamic head, and W_s is the pounds of steam consumed per hour. Knowledge of the cost per pound of steam provides the operator with a ready means of computing the operating cost of a unit.

Speed

The flow of a pump will produce against a given head is a definite function of its speed. It therefore becomes important to know the speed, in rpm, of any pump being tested. Pump manufacturers normally draw their test curves on the basis of the contract speed. If the field test conditions are different, the head capacity and break horsepower for these different speeds must be corrected.

The speed of synchronous motors on utility-generated or paralleled power can be considered as exactly synchronous, or name-plate speed. However, induction or squirrel-cage motors will vary in speed slightly, depending on their loads—the lower the load, the closer the speed approaches synchronous; the higher the load, the lower the speed. The speed can be checked easily with a good hand tachometer off of the outboard end of the motor or pump shaft, or by a hand-held counter and stopwatch. The speed should, of course, be checked for each test point.

The speed of an engine or turbine must also be considered as variable. If a step-up or reduction gear is used, determination of the pump speed will have to allow for the tooth ratio of the gear.

After the speed at each test point has been determined, it is often only necessary to plot the speed as a function of the flow. It should be noted on the curve that the head and capacity are based on speeds "as run." However, the operator may want to convert or correct the performance to the same speed as the manufacturers test curve for the pump, or to a slightly different speed to determine the characteristics of the unit with a different type of motor or driver. For example, in the sample test, the speed was corrected to 1,200 rpm to ascertain the characteristics if the same pump were driven with a synchronous motor.

Calculation of Results

After the measurements have been made and recorded as in Table 2, the results calculated as shown in Table 3, the operator can then plot a series of curves representative of the pump's performance.

The flow, Q, will be the actual flow, measured in gallons per minute.

The total dynamic head will be the sum of the difference between the discharge head and the suction head plus the velocity head:

$$H = h_d - h_s + h_v \quad \text{.....(12)}$$

in which h_v represents the change in static head or measured head due to the difference in velocity between the suction and discharge pipes. If they are the same size, $h_v = 0$. However, the suction pipe normally is larger in diameter than the discharge pipe. The velocity head is calculated from

$$h_v = \frac{Q^2}{K} \quad \text{.....(13)}$$

using the appropriate K value from Table 4. It should be noted that if pressures are measured at a point in the line, different in diameter from the suction or discharge, the velocity head must be based on the diameter at the point of measurement.

The water horsepower will be:

$$whp = \frac{Q\,H}{3{,}960} \quad \text{.....(14a)}$$

which is exact for water at 68F and is reasonably accurate through the range from 32F to 100F. Above 100F, the equation must take into account the specific gravity of the liquid being pumped:

$$whp = \frac{Q\,H\,W}{3{,}960 \times 62.32} = \frac{Q\,H\,S}{3{,}960} \quad \text{(14b)}$$

The speed does not actually enter into the calculations unless the operator wants to analyze the results in terms of using a driver with a slightly different speed or wants to correct the speeds to the manufacturer's original test speed. To correct for a change of speed, it is first necessary to calculate the test point as run. Next, the flow, the head, and the brake horsepower are corrected by:

$$\frac{n_1}{n_2} = \frac{Q_1}{Q_2} = \left(\frac{H_1}{H_2}\right)^{1/2} = \left(\frac{bhp_1}{bhp_2}\right)^{1/3} \quad \text{.....(15a)}$$

Eq. 15a can be broken down into the three separate corrections, as follows:

Correction for flow:

$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2} \quad \text{.....(15b)}$$

Correction for head:

$$\frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2 \quad \text{.....(15c)}$$

Correction for power:

$$\frac{bhp_1}{bhp_2} = \left(\frac{n_1}{n_2}\right)^3 \quad \text{.....(15d)}$$

The corrections are easily made on a slide rule by utilizing the power ratios of the C-D, A-B, and K scales.

The efficiency will remain unchanged for speed corrections of 10 to 20 per cent, so the efficiency for each point can be noted from the original speed. However, it is often useful to check all corrections by refiguring the efficiency from the corrected results. If the figures are not the same, there has been a "slide rule slip."

Plotting the Results

It is the accepted practice to show pump performance by plotting the results against "flow." One or more curves are drawn: head *vs* flow; efficiency *vs* flow; bhp *vs* flow; or any other desired quantity *vs* flow (Fig. 3). These curves serve very useful purposes. They tend to point out any erroneous test points and give a continuous picture that allows the operator to cover the full range of a pump's performance with only five to ten points.

When a variable-speed drive is used, it is often useful to plot several different speeds covering the complete range of the driver, which presents a complete picture of the speed and power required to fill each condition of head and flow.

In addition to the test curve, it often will be useful to plot other curves that are calculated from the basic curve and the particular installation. Useful curves are: kilowatt-hours *vs* flow; power cost ($ per day) *vs* flow; time to fill a reservoir *vs* height of the reservoir; or combined head capacity characteristics of several pumps in series or in parallel. Through different types of curves, there is a vast amount of information that can be shown and studied. This information may well form a very useful part of the operation, maintenance, and planning of a pump installation.

Centrifugal Pump Theory

The theory of how a centrifugal pump operates is intimately tied into actual performance. Therefore, a brief review of the basic theory of centrifugal pump operation is in order. The centrifugal pump (see Fig. 3) is a means of converting mechanical energy, the output of a motor or engine, into hydraulic energy in the form of increased head or pressure in the fluid being pumped. Exactly how and where the conversion takes place within the pump has been well covered in numerous articles and texts, and need

THE AUTHOR (right) is logging and checking pump bearing conditions at the Trenton (N. J.) Water Works Pumping Plant.

Table 2

Pump Test Record

By: FWS Date Test No. 42-1-1
Pump: High Head Pump No. 42
Rating: 6950 gpm 220 ft head 1180 rpm 439 bhp
Type: Single stage, 16" side suct. 14" side disch.

		Test Point No.	1	2	3	4	5	6
1	Venturi man. deflection	in. hg.	9.5	7.05	3.65	1.70	0.51	0
2	Venturi constant		2,707	→	→	→	→	→
3	Flow	gpm	8,350	7,050	5,180	3,520	1,930	0
4								
5	Suction man. deflection	in. hg.	—7.9	—7.1	—6.3	—5.6	—5.2	—4.8
6	Suction	ft.	—9.0	—8.0	—7.2	—6.4	—5.9	—5.4
7	Elev. corr.	ft.	+0.3	→	→	→	→	→
8	Corr. suct. head	ft.	—8.7	—7.7	—6.9	—6.1	—5.6	—5.1
9								
10	Disch. gage reading	psig	72.6	91.9	102.9	108.6	112.3	116.1
11	Disch. gage corr.	psig	—2.2	—2.4	—0.8	0	0	+.2
12	Corr. press	psig	70.4	89.5	102.1	108.6	112.3	116.3
13	Disch. head	ft.	162.7	206.9	236	251	259.5	268.3
14	Gage elev. corr.	ft.	+1.6	→	→	→	→	→
15	Corr. disch. head	ft.	164.3	208.5	237.6	252.6	261.1	269.9
16								
17	Velocity head constant	k		36,250,000	→	→	→	→
18	Velocity head	ft.	1.9	1.4	.7	.3	.1	0
19								
20	Total dynamic head	ft.	174.9	217.6	245.2	259	266.8	275
21								
22	Speed	rpm	1,180	1,180	1,183	1,186	1,192	1,192
23	Water power	hp	369	387	321	230	130	0
24	Wire to water effy	%	72	81.3	78.8	67.3	45.7	0
25	Pump effy	%	78.3	88.3	85.7	73.1	49.7	0
26	Volts avg. 3ø	v	442	441	442	440	440	442
27	Amp. avg. 3ø	A	575	536	463	394	333	289
28	Power factor		.87	.87	.86	.85	.84	.83
29	Kw input	kw	383	356	305	255	213	183.5
30	Motor hp input	hp	513	477	408	342	285	246
31	Motor effy	%	92	→	→	→	→	→
32	Motor hp output	hp	472	438	375	315	262	226
33		Test corrected to 1200 rpm						
34	Flow	gpm	8,490	7,170	5,260	3,560	1,943	0
35	Total dynamic head	ft.	180.8	225	252	265	271	279
36	Input power	hp	496	460	391	327	267	230
37	Pump effy	%	78.3	88.3	85.7	73.1	49.7	0
38								
39								
40	Notes: Mechanical operation normal. 20" mercury column on suction side at side top gage line							
41	dry. 0—200 psi gage on disch. at side top calibrated 8/8/57. Plant venturi 16.16" x 11.00"							
42	used C = .985, Water 67° F. operation to date 1200 hours.							
43								

not be of concern in the actual pump testing.

In simplest terms, the performance of the pump can be expressed as: ENERGY IN WATER AT SUCTION + ENERGY INPUT = ENERGY in WATER AT DISCHARGE + LOSSES.

The energy in water at any time can be represented by Bernoulli's theorem, which states that the total energy per unit is a constant. This concept can be represented by:

$$H = h_g + \frac{V^2}{2_g} + Z \quad \text{.....(16a)}$$

Multiplying Eq. 16 by the pounds per second flowing through the pipe gives:

$$0.00223\ Q\ w\ H = 0.00223\ Q\ w$$

$$\left(h_g + \frac{V^2}{2_g} + Z\right) = 550\ whp \quad \text{.(16b)}$$

In Eq. 16*b*, 0.00223 Q represents the cubic feet per second flowing in the pipe if Q is in gallons per minute; 0.00223 Q w is the pounds of water per second. The term h_g represents the pressure as read from a gage or manometer, in feet of head or static head. $\frac{V^2}{2_g}$ represents the portion of the head in the form of velocity energy. Z represents the elevation above or below a given datum. This factor is neces-

sary because the amount of energy in a given flow in a pipe depends on the pipe level; there is much greater energy if the reference plane is at a level some feet below the pipe. Whp represents the actual horsepower in the water under the prescribed conditions.

As an example, in any one pump the quantity of water flowing in at the suction and out at the discharge is a constant. The change of pressure read on the gage represents the increase in static pressure. The velocity will normally be different in the suction and discharge pipes because of the smaller diameter of the discharge. Because the elevations of the two gages may be different, there may be different distances to the datum line. The equation for the flow in the suction pipe subtracted from the equation for flow in the discharge pipe will represent the increase in energy across the pump:

$$0.00223\,Q\,w\,(h_{gd} + \frac{V^2_d}{2_g} + Z_d) - 0.00223\,Q\,w\,(h_{gs} + \frac{V^2_s}{2_g} + Z_s) = 550\,whp \quad \text{(17a)}$$

Rewriting Eq. 12 for water at 68F:

$$(h_{gd} + Z_d - (h_{gs} + Z_s) + \left(\frac{V_d^2 - V_s^2}{2_g}\right) = \frac{550\,whp}{0.00223\,Q\,w} = \frac{3{,}960\,whp}{Q} \quad \text{(17b)}$$

The left-hand portion of Eq. 17*b* is known as the "total dynamic head." $(h_{gd} + Z_d)$ is the reading on the discharge gage, converted to feet of water and corrected in elevation to the datum, normally the horizontal centerline of the pump; $(h_{gs} + Z_s)$ is the reading on the suction gage converted to feet of water and corrected in elevation to the datum. The datum must be the same for both the suction and discharge readings. $\left(\frac{V_d^2 - V_s^2}{2_g}\right)$ is the change of velocity head in feet of water and is calculated from the pipe sizes and flow. The three combined are the total dynamic head:

$$H = (h_{gd} + Z_d) - (h_{gs} + Z_s) + \left(\frac{V_d^2 - V_s^2}{2_g}\right) \quad \text{(18)}$$

Substituting in Eq. 17*b* gives:

$$whp = \frac{H\,Q}{3{,}960} \quad \text{(19)}$$

Table 3
Calculation of Typical Test

(Line numbers refer to horizontal line on data sheet. Numerical examples are for Test Point No. 1)

Line 1. Read in inches of mercury and recorded.
9.5

Line 2. Calculated prior to test and constant for all test points.
2,707

Line 3. Calculated.
Line 2 $\sqrt{}$Line 1 = 2,707 $\sqrt{}$9.5 = 8,350

Line 5. Read in inches of mercury and recorded. Pressure is below atmospheric, so sign is negative.
—7.9

Line 6. Calculated.
1.131 (Line 5) = 1.131 × —7.9 = —9.0

Line 7. Measured prior to test and constant for all readings. Gage line is air-filled, so correction equals distance between gage tape and datum line of pump. Gage is above datum, so correction is positive.
+0.3

Line 8. Calculated.
Line 6 + Line 7 = —9.0 + 0.3 = —8.7

Line 10. Discharge gage read and recorded.
72.6

Line 11. Gage had been calibrated prior to test, correction from calibration curve.
—2.2

Line 12. Calculated.
Line 10 + Line 11 = 72.6 + (—2.2) = 70.4

Line 13. Calculated.
(Line 12) × 2.31 = 2.31 × 70.4 = 162.7

Line 14. Measured prior to test and constant for all readings. Gage line is filled with water, so correction equals distance from centerline of gage to datum line. Gage is above datum, so correction is positive.
+1.6

Line 15. Calculated.
Line 13 × Line 14 = 162.7 + 1.6 = 164.3

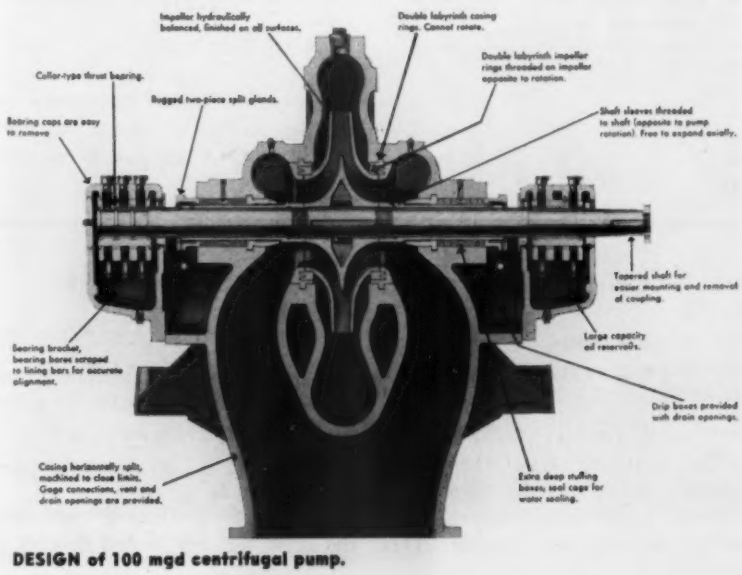
Line 17. From Table 2 for 16 by 14 in. pump.
36,250,000

Line 18. Calculated.
$$\frac{(\text{Line 3})^2}{\text{Line 17}} = \frac{8{,}350^2}{36{,}250{,}000} = 1.9$$

Line 20. Calculated.
Line 15 — Line 8 + Line 18 = 164.3 — (—8.7) + 1.9 = 174.9

Line 22. Measured and recorded.
1,180

Line 23. Calculated.
$$\frac{\text{Line 20} \times \text{Line 3}}{3{,}960} = \frac{174.9 \times 8{,}350}{3{,}960} = 369$$


Impeller hydraulically balanced, finished on all surfaces.
Double labyrinth casing rings. Cannot rotate.
Double labyrinth impeller rings threaded on impeller opposite to rotation.
Collar-type thrust bearing.
Rugged two-piece split glands.
Shaft sleeves threaded to shaft (opposite to pump rotation). Free to expand axially.
Bearing caps are easy to remove
Tapered shaft for easier mounting and removal of coupling.
Large capacity oil reservoirs.
Bearing bracket, bearing bores scraped to lining bars for accurate alignment.
Drip bonet provided with drain openings.
Casing horizontally split, machined to close limits. Gage connections, vent and drain openings are provided.
Extra deep stuffing boxes, seal cage for water sealing.

DESIGN of 100 mgd centrifugal pump.

Table 3 (Continued)
Calculation of Typical Test

(Line numbers refer to horizontal line on data sheet. Numerical examples are for Test Point No. 1)

Line 24. Calculated.

$$\frac{\text{Line 23} \times 100}{\text{Line 30}} = \frac{369 \times 100}{513} = 72$$

Line 25. Calculated.

$$\frac{\text{Line 23} \times 100}{\text{Line 32}} = \frac{369 \times 100}{472} = 78.3$$

Line 26. Measured, averaged, and recorded.
442

Line 27. Measured, averaged, and recorded.
575

Line 28. Measured and recorded.
0.87

Line 29. Calculated.

$$\frac{\text{Line 26} \times \text{Line 27} \times \text{Line 28} \times \sqrt{3}}{1{,}000} = \frac{442 \times 575 \times 0.87 \times 1.732}{1{,}000} = 383$$

Line 30. Calculated.
Line 29 × 1.341 = 383 × 1.341 = 513

Line 31. Motor efficiency from motor manufacturer's data as a function of Line 30 or as a constant.
92

Line 32. Calculated.

$$\frac{\text{Line 30} \times \text{Line 31}}{100} = \frac{513 \times 92}{100} = 472$$

Line 34. Calculated for 1,200 rpm.

$$\text{Line 3} \left(\frac{1{,}200}{\text{Line 22}}\right) = 8{,}350 \left(\frac{1{,}200}{1{,}180}\right) = 8{,}490$$

Line 35. Calculated for 1,200 rpm.

$$\text{Line 20} \left(\frac{1{,}200}{\text{Line 22}}\right)^2 = 174.9 \left(\frac{1{,}200}{1{,}180}\right)^2 = 180.8$$

Line 36. Calculated for 1,200 rpm.

$$\text{Line 32} \left(\frac{1{,}200}{\text{Line 22}}\right)^3 = 472 \left(\frac{1{,}200}{1{,}180}\right)^3 = 496$$

Line 37. Calculated for 1,200 rpm as a check on Lines 34, 35, and 36, and should agree with Line 25.

$$\frac{\text{Line 34} \times \text{Line 35} \times 100}{\text{Line 36} \times 3{,}960} = \frac{8{,}490 \times 180.8 \times 100}{496 \times 3{,}960} = 78.3$$

TABLE 4
Velocity Head Constants for Common Pump Sizes*

$$h_v = \frac{Q^2}{K}$$

Pump Suction Dia., in.	Pump Discharge Dia., in.	Vel. Head Constant, K
2	1	413
2	1½	2,830
2½	2	10,600
3	2	7,700
3	2½	29,300
4	2	6,580
4	3	45,500
5	3	36,000
5	4	167,000
6	3	33,250
6	4	123,000
6	5	435,000
8	4	105,800
8	5	285,000
8	6	733,000
10	4	101,200
10	5	257,000
10	6	575,000
10	8	2,680,000
12	8	1,970,000
12	10	7,500,000
14	8	1,768,000
14	10	7,400,000
14	12	17,350,000
16	10	4,550,000
16	12	11,700,000
16	14	36,250,000
18	16	67,000,000
20	18	118,600,000
24	20	119,150,000
30	24	217,000,000
36	24	160,000,000
36	30	606,000,000

*Constants for other sizes of pumps can be calculated from

$$K = \frac{385.6}{\frac{1}{D_d^4} - \frac{1}{D_s^4}}$$

in which D_d is the discharge diameter and D_s is the suction diameter, both in inches. The equation has been derived from the basic relationship $h_v = \frac{V_d^2}{2g} - \frac{V_s^2}{2g}$.

Pressure has been expressed in terms of feet of head rather than pounds per square inch. Pump engineers prefer to use feet of head for several reasons. First, it simplifies all elevation corrections. The discharge of a centrifugal pump at a given speed and capacity is a definite head in feet, regardless of the temperature or the specific gravity of the liquid. Because most gages read in pounds per square inch, it will be necessary to convert back and forth from psi to feet. This can be done easily by:

$$h_g = \frac{144\, p_g}{w} \quad \text{.....(20a)}$$

$$p_g = \frac{h_g\, w}{144} \quad \text{.....(20b)}$$

Unfortunately, not all of the power imparted to the shaft of a pump is converted to useful pump output (whp). Some of it is dissipated as heat in the bearings due to friction, some as heat at the packing or shaft sleeves, and still more as friction between the pump and the water or friction in the water itself. Other power is lost by leakage from the discharge portion of the pump back to the suction through the impeller rings and breakdown bushings.

The less these losses are, the greater the efficiency of the pump. Written as an equation:

$$E_p = \frac{whp}{bhp} \times 100 \quad \text{.....(21)}$$

in which whp is the power output and bhp is the power input. This efficiency is the measure of how good a given pump is—or how bad it is—at a given capacity. The determination of the efficiency is one of the prime reasons for testing. Comparatively, it is the best indication of the internal condition of a pump.

References

1. "A.S.M.E. Power Test Codes: Centrifugal Pumps." Amer. Soc. Mech. Eng., 29 W. 39 St., New York, N. Y.
2. "Standards of Hydraulic Institute, Centrifugal Pump Section." Hydraulic Inst., 90 West St., New York, N. Y.
3. "Fluid Meters, Their Theory and Application. Part I." Amer. Soc. Mech. Eng., 29 W. 39 St., New York, N. Y

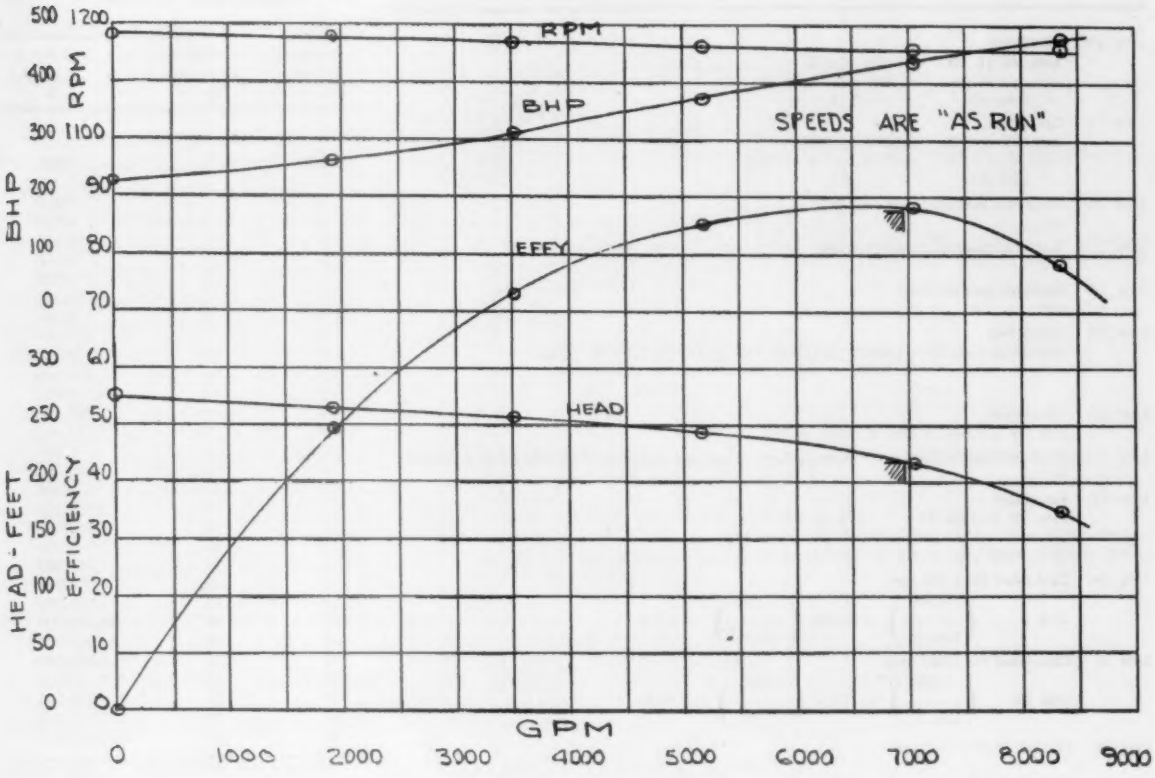
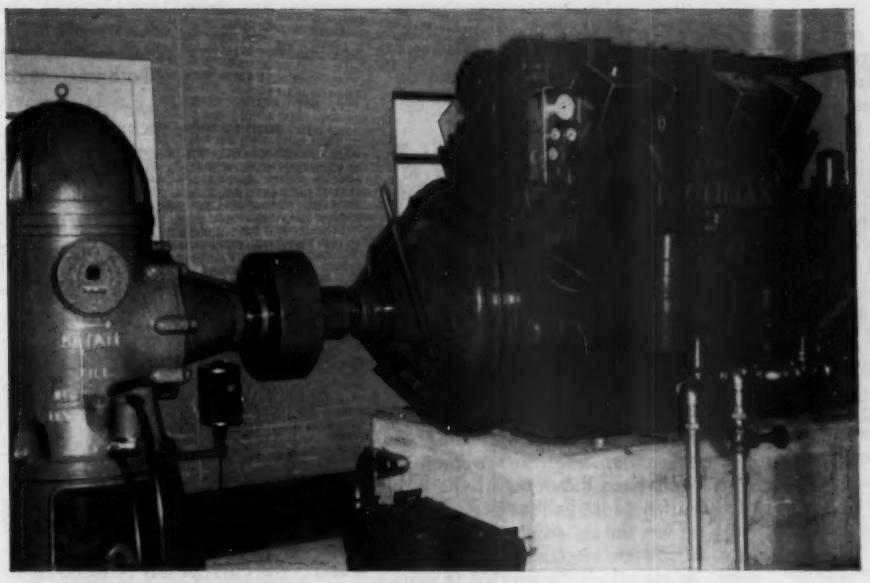
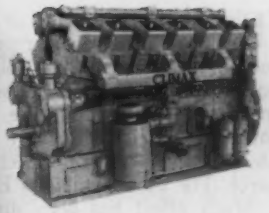


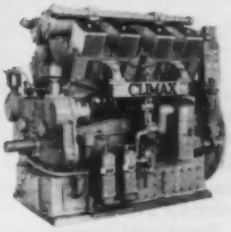
FIG. 3—Typical pump test curve.

CLIMAX MUNICIPAL ENGINES

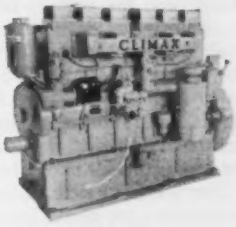




V-125—12 cylinder,
605 max. hp. at 1200 rpm.
V-122—12 cylinder,
520 max. hp. at 1200 rpm.



V-85—8 cylinder,
390 max. hp. at 1200 rpm.
V-80—8 cylinder,
340 max. hp. at 1200 rpm.



K-75—6 cylinder,
304 max. hp. at 1200 rpm.
K-67—6 cylinder,
265 max. hp. at 1200 rpm.

IN SEWAGE TREATMENT PLANTS everywhere Climax engines power sewage pumps, blowers and generators. Burning sludge gas, and utilizing heat from jacket water and engine exhaust gas to heat digesters and buildings, they effect big savings. Capable of operation on natural gas, butane, gasoline, or any combination. For continuous duty service in sewage plants—eight rugged Climax models: 12, 8, 6, 4 cylinders.

IN WATER WORKS over 100 cities depend on Climax engines... for prime power, or to take over when normal power for pumps is interrupted or fails... and to drive pumps during peak loads as supplementary power. Burning natural gas, butane or gasoline Climax Water Works engines range in size to 600 hp.

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CL-106

BASIC MAX. ENGINE HP (Natural Gas and Gasoline) ①					600	700	800	900	1000	1100	1200
MODEL	No. of Cyls.	Bore & Stroke	Displ.	Torque @ RPM	BRAKE HORSEPOWER AT SPEEDS INDICATED						
R-110	4	6⅛ x 7	824	610 @ 800	68	83	94	105	115	123	125
R-165	6	6⅛ x 7	1238	930 @ 750	105	123	140	156	170	183	192
K-67	6	7 x 7	1616	1240 @ 805	140	165	188	210	230	248	265
K-75	6	7½ x 7	1855	1410 @ 800	160	186	214	240	265	286	304
V-80	8	7 x 7	2155	1610 @ 850	178	210	241	272	300	323	340
V-85	8	7½ x 7	2474	1860 @ 900	207	249	285	317	345	370	390
V-122	12	7 x 7	3232	2440 @ 900	280	330	380	420	460	490	520
V-125	12	7½ x 7	3711	2880 @ 850	310	370	435	490	540	580	605

① Basic engine includes ignition, maximum carburetion, and water pump. Ratings indicate maximum horsepower.

CLIMAX ENGINE MANUFACTURING CO. • FACTORY—CLINTON, IOWA
DIVISION OF WAUKESHA MOTOR COMPANY

Practical Electricity in the Plant

By MARSDEN C. SMITH

Chief Engr., Dept. of Public Utilities, Richmond, Va.

Volt Equals Pressure

THE VOLT is the unit of electrical *pressure*. Just as water pressure is measured in terms of pounds per square inch, electrical pressure is measured in volts. Voltage is sometimes expressed as the 'emf' which is an abbreviation of electromotive force. The usual symbol is E.

Much effort has been directed to standardizing electrical voltages (pressures), but still a "110 volt circuit" may actually range from 110 to 125 volts or even more. In fact, most residential demands supplied by public utilities as "110 volt" usually are 120 or 125 volts.

Larger current consuming devices such as ranges are built for 3-wire service; phase to neutral (ground) being "110 volts"; phase to phase being "220 volts." If the "110 volts" is actually 120 volts, then the "220 volts" becomes 240 volts.

Fractional horsepower motors usually are designed to operate from the 110 volt lighting circuits. Larger motors are available for 110, 220, 440, 2,200 and 13,200 volts. In existing installations, the voltage often is fixed by the original design; but in new installations motors up to two hundred horsepower generally are operated at either 220 or 440 volts. Larger installations warrant the advice of an experienced electrical designer to secure the best economy and safety.

Extra-heavy fittings and greater precautions are necessary when greater water pressures are used; so too, must greater care be taken both of life and property when greater electrical pressures are used. However, pressures of as little as 110 volts, in common use, *may prove fatal* and care should always be taken to avoid personal contact, especially when hands or feet are wet.

Incandescent filament electric lamps are highly sensitive to voltage change from that for which they were designed. Particularly is this true in its effect on the life of the lamp. For example; lamps rated for 110 volts and operated at 118 volts would increase the cost of lamp renewals by almost 300 per cent.

Fluorescent lamps while not as seriously affected by over-voltage, are subject to ballast failure and rapid loss of light output if started and operated at above their voltage rating. Of particular interest to the operator is the effect of humidity and temperature on these lamps. If the room temperature is 50° F. or lower, or if the humidity is above 70 per cent, then rapid depreciation and otherwise unsatisfactory operation is to be expected.

Electric motors are not nearly so sensitive to voltage change as are lamps; nor are heating devices—particularly those that are thermostatically controlled. Motors will operate successfully at applied voltages within 10 per cent above or below their rated voltage. Greater voltage variation will generally cause excessive heating or unsatisfactory operation.

Ampere Equals Rate of Flow

THE AMPERE is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally I. In print, ampere is sometimes abbreviated to "Amp."

Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamp, heating device, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. Each electrical unit (except lamps) should have its normal current rating stamped upon its name plate. Lamp current is approximately determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus, currents to this extent are standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should *never* permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance in a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current nearer the source of power. For example: Five 1,000 watt lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from the nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Ohm Equals Resistance

THE OHM is the unit of electrical *resistance*. In equations its symbol is R.

If we close the spigot, even though there is water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact is distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed later) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a

result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Watt Equals Power

THE WATT is the unit of electrical *power*. The most commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is W; for the Kilowatt KW. The mechanical unit of power is horse-power; one horse-power (HP) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

However substituting for (E) from equation (1), wherein $E = RI$, we have:

$$P = RI^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

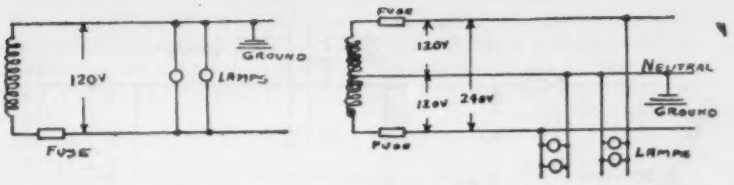
$$P = \frac{E^2}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Now it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

Direct and Alternating Current

Formula (1) applies only to circuits that contain nothing but resistance, no inductance or capacity; or those circuits in which the "frequency" is zero. If two wires A and B are left connected to the terminals of a battery, the current flow in the wires will be in one direction, thus becoming a "direct current" (unidirectional current). Such circuits usually are referred to as D.C. circuits and include battery supplied devices. These circuits are seldom used for public power except in limited areas of older cities.

If now we reverse the connections of the two wires each ½ second, then the current will flow in one direction for ½ second, but will flow in the reverse direction during the next ½ second. Obviously the current will then flow in the same direction in the same wire commencing once each second. Such a circuit would be defined as an "alternating current" (or voltage, or circuit) having a *frequency* of one *cycle* per second. Thus it is evident that "frequency" is the number of "cycles" per second, or ½ of the number of times the current flow reverses in each second.



Figs. 1 and 2—Circuit diagram

The almost universal standard frequency is now 60 cycles per second, and the time-potential value of the voltage closely follows the sine law. This latter fact permits the use of vectors in the solution of alternating current problems, but such solutions are beyond the scope of these notes.

If a direct current is caused to flow through a coil of wire have a resistance of R ohms, wound around an iron core, then—since the frequency is zero—formula (1) can be used. But if the current is made alternating, the value of R seems to increase more and more as the frequency is increased. This is because the coil and its iron core form an "inductance" the nature of which is mechanically similar to a heavy fly-wheel. Inductance opposes any change of current flow and thus prevents the current from being proportional to the voltage (roughly speaking). If the coil has no resistance (academic assumption) then this inductive effect would cause the current to lag 90° behind the voltage causing it to flow. Parenthetically, "capacity" (insulated plates or parallel wires), which is an effect negligible in water plant installations, causes the current to lead the voltage by 90°. Thus, if the capacity effect is equal to the inductive effect, these cancel and the circuit behaves as if it contained neither capacity nor inductance.

Thus in an alternating current circuit, equation (1) becomes:

$$E = ZI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

in which Z is the *impedance* of the circuit and its value is expressed in ohms.

Many electrical appliances, including heating appliances and lamps have little if any magnetic effect (hence little inductance) and so may be used equally well in alternating or direct current circuits. Motors must be of a special design if they are to be used on both AC and DC circuits; and transformers must never be connected to DC supplies.

Power Factor

The above equation (2) is generally used in the form:

$$P = EI \cos \theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

In which the Cos Θ is the *power factor* of the circuit sometimes abbreviated PF. The angle Θ is the time displacement between the voltage and the current which, as has been shown, is determined by the relative values of resistance and the inductive and capacity effect in the circuit. Since this may (theoretically) be of any value between zero and 90°, the power factor may have any value between zero and one.

The actual mathematical value of the power factor of circuits is difficult to compute, but may be readily determined by an instrument designed for the purpose or by the simultaneous readings of power, voltage and current by means of a wattmeter, voltmeter and ammeter.

As has been stated, the PF of heating appliances and lamps is quite

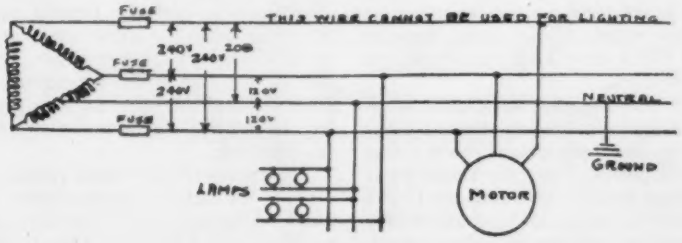


Fig. 3—Circuit diagram

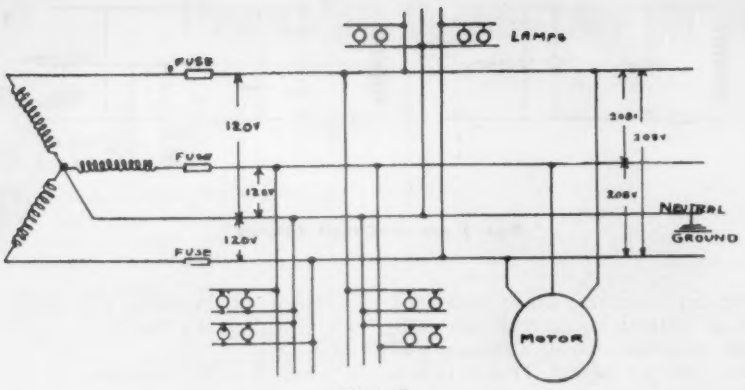


FIG 4

Circuit diagram—Fig. 4

nearly unity.

The PF of motors and transformers vary through rather wide limits, being nearly zero for transformers at no load. As their name implies, induction motors also have relatively bad power factors, small units being as low as 60 per cent at light loads and large motors of this type at full load not over 94 per cent.

Synchronous motors may operate at from 60 per cent lagging to the same value leading, thus cancelling the low PF of inductive units on the same circuit.

Low power factors are serious because of the greater current required for the same power, thus increasing the power loss in the wiring of the power supply. The effect on the constancy of voltage is also quite serious; in fact power companies frequently offer reduced rates to encourage the use of high power factor equipment.

Obviously the operator can do but little to improve the power factor of his system except in the selection of the type of motor, as more fully discussed later.

The Kilowatt-Hour

The kilowatt hour is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at an average rating of 600 watts, there is used 600 x 2 = 1200 watt-hours, or 1.2 KyHrs.

The volt ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in volt-amperes (VA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load determines its power output. Thus we see that:

$$KW = Kva \times \cos\theta \quad \ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume one-half of the load to be lamps and one-half small motors, we may approximate the average power-factor as 82 per cent. Hence, by equation (7) we find Kw = 100 x 0.82 or 82 Kw to be the safe load for this case.

Grounding

Grounding is the connection of one wire of an electric system or any metallic part of the system to the earth.

All alternating circuits must be grounded and the grounded wire is called the *ground or neutral;* the wires not grounded are called the *hot* or *phase* wires. The neutral is the point of equal potential to the phase wires (See Figs. 2 and 4). The neutral of Fig. 3 is neutral to the two bottom but not the upper phase wire. If there were no ground of the transformer neutral or of the phase wires in Fig. 3, the neutral would be an imaginary point.

The ground must be equal in size or larger than the phase wires; and it must not be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

The approved maximum voltage to ground for any wire connected to standard "house-wiring" switches and receptacles is 150 volts. This is why only one phase of a 200 volt delta system may be used for the lighting circuits. Where greater voltage exists for motors etc., the wires must be enclosed in a metal conduit and the frames of the motors and conduit system electrically connected and grounded. Grounding should be carefully inspected at sufficiently frequent intervals to make certain that the essential protection it provides is in perfect condition.

Grounds should be carefully made, preferably use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼ inch pipes, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection when shorted, should blow a 30 ampere fuse at 120 volts.

The necessity for grounding the electric circuits is to prevent dangerous high potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous value. The wiring for lighting systems of buildings is designed for maximum 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire would be started, or perhaps a member of your family would be killed. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have prevented.

Phase

Phase is a term also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart and in the "Three-Phase" system they are 120 degrees apart.

In another sense, it may be considered that there are in effect one or two or three circuits in the single, the

two or the three phase systems. Of course the load and power factor in the different phases may differ, and hence the computation of power in polyphase circuits becomes difficult and beyond the limits of these fundamentals.

Circuits

The single phase, two-wire circuit shown in Fig. 1 is the simplest and most used connection. As seen in figures 2 to 4, it is the connection used to supply lamps and small motors and appliances in even the largest systems.

The single phase, three-wire circuit shown in figure 2 is really two single phase circuits with one wire in common. It is used when more power is needed than can economically be supplied by the two-wire system; also it permits "220 volt" units to be connected to the two fused wires and yet the system has no more than 110 volts to ground. When the loads are identical the neutral wire carries no current, but since one fuse may *blow* (melt) the neutral must carry the same current as the phase wires and hence must be of the same size. But even then this system saves one of the four wires that would be required for two two-wire circuits.

The three phase circuits shown in Figs. 3 and 4 are really three single-phase circuits connected together, with the important difference that the three phases are equally spaced in time relationship (120° apart). There are two connections generally used for three phase circuits, the "Y" and the "delta," each of which has certain advantages. In general the "delta" is more reliable, when used for power only, in that if one transformer is lost the remaining two can supply 87 per cent of their combined capacity. But to off-set this when lighting is needed, unless the motor load is small enough to be operated at 110 volts, one of the neutrals of one of the transformers must be grounded, thus increasing the chances for power failure.

Then, too, many power companies will limit the lighting load that may be placed on the one phase supplying it (see Fig. 3); and the lighting is badly affected with "flickering" particularly if the motors are frequently started and stopped as for elevators.

The "Y" connection has the advantage that the lighting load can be divided between the three phases, but the three-phase voltage for motor use is less than that for which motors are usually designed.

Hence it may be said that for large loads three phase systems are always used. In one water treatment plant the lighting and motors of less than 5 HP are supplied by three "Y" connected transformers; the large motors and elevators are supplied from three DELTA connected (480 volt) transformers.

The formula for power in the different systems, with equal load and PF, is given in Table 1.

Fuses and Circuit Breakers

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a pre-determined or dangerous rate.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. The National Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and, thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flameproof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type known as the "refillable type," permits the renewal of the fuse link and the use of the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker may be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of a circuit breaker is usually actuated by an

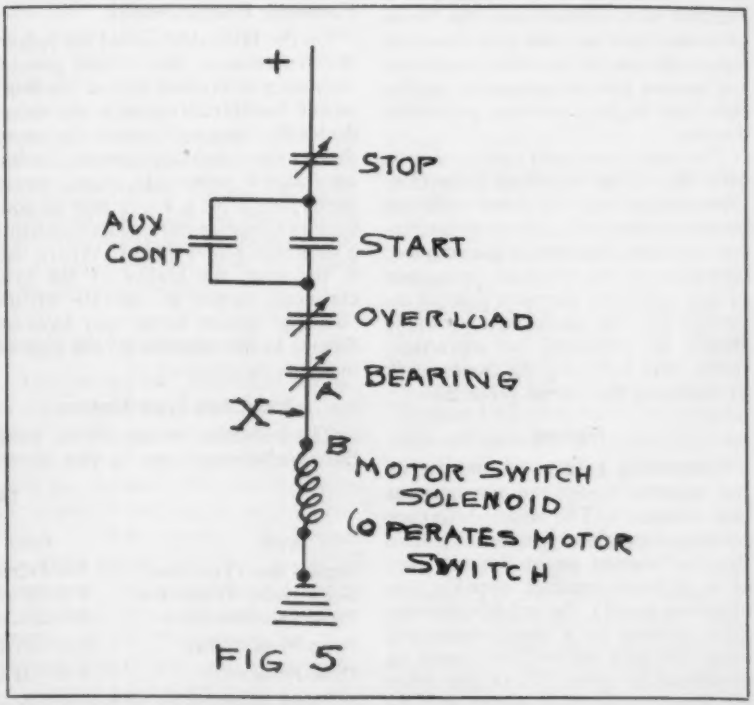


Fig. 5—Wiring diagram

auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are only three:

(1) *The Instantaneous Type* — dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type.* Here an air bellows with an adjustable escape valve is used in place of the oil dash-pot described above. This type is now essentially obsolete.

(3) *The Induction Type.* This relay is more expensive than those above mentioned, but its use is justified in the protection of all important circuits. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. A too frequent operation of the overload protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of enlarging the circuit protection.

Motors

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences which will be mentioned later.

Synchronous Type Motors

At a given frequency the speed of a synchronous motor may be determined by the equation:

$$N = \frac{120f}{P} \quad \ldots\ldots(8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots(9)$$

From this it is evident that the maximum speed for a 60-cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60-cycle motors, is the constant 7200 divided by the number of poles; and since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900 . . . RPM. One of the greatest limitations of the standard synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements constitute a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

Induction Type Motors

The induction motor differs from the synchronous type in that it requires no separate excitation and it operates at a variable speed, as contrasted to the constant speed synchronous motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four, or any even number of poles, just as is the stator of a synchronous motor; hence, it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring a relatively small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But, while they will operate successfully under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not as rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble.

We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of slip. As stated above, the standard squirrel-cage motor slip varies from virtually nothing at no load to about 3 per cent at full load. With the wound motor, external resistance may be added to the rotor circuit, the effect of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed be reduced.

TABLE 1

System	Power		Max. Volts to Ground
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E = 120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E = 240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E = 120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E = 240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E = 207.8	120

* Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horsepower required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horsepower output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of transformers is advisable. The standard transformer consists of two stationary coils of wire, insulated from each other and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

The coil or the turns connected to the power supply is the primary; the second winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase as readily as to reduce the voltage. Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead" when in fact the 110-volt side was still energized, *thus producing normal high voltage in the primary.*

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, *if kept cool,* can safely carry much greater than rated loads. Cold winter weather and artificial ventilation may effectively cool transformers submerged in oil, but hot weather and hot locations are dangerous. Oil tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

Ratings

The rating of most units of electrical apparatus—such as motors, transformers, etc.—is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while others base their estimates upon a rise of only forty degrees. After all, this simply means that a given motor rated at 100 HP, at 40-degree rise, would be rated at 125 HP at 55 degrees rise. All things considered, it seems to be the consensus of opinion, and a wise dictate, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise of not to exceed forty degree centigrade.

Circuit Wiring Diagrams

The remote and automatic control of electric motor driven pumps and other electrical equipment now requires that the operator be familiar with the diagrams that should always be available for repair and maintenance of such circuits. Most non-electrical people feel that a wiring diagram is too involved for them to understand. It is really surprising how simple a wiring diagram can be —if it is complicated, it is unnecessarily so.

In Fig. 5 a simple remote motor control circuit is shown. Note first that the circuit is complete and that the contacts must carry the current required by the solenoid, since they are in series with the solenoid.

Contacts that normally are closed *before starting* are marked with an arrow. Since all contacts except *start* are closed all that is needed to start the motor is to close the *start switch* (press start button). But, since that switch must be open as soon as pressure is removed, an auxiliary contact must be provided which closes when motor switch closes.

When the auxiliary contact is closed the circuit is completed even with the *start switch* open, and so the motor continues to run until something causes the control circuit to become "opened." Normally this would be done by pushing the *stop* button opening the *stop* switch. But if a bearing overheats, or if the motor is overloaded, then the opening of either of these switches will also open the circuit; thus deenergizing the motor switch solenoid, opening the motor switch, and stopping the motor. Now assume that the wire breaks, thus opening the circuit, or that a bare wire touches "ground" at "X." The nature of the trouble could be determined by (a blower fuse (short) indicating bare wire touching; or (b) voltage indicated by test lamp to be at A but not at B. All wiring diagrams are nothing more than elaborations of this simple circuit and certainly are within the grasp of anyone willing to figure them out.

Wires

Because of the dampness normally existing in water and sewage plants, money invested in adequate conductor protection is wisely invested.

For important circuits, 1000 volt rubber insulation is recommended to carry up to 440 volts. For higher volts, an insulation of at least twice the operating value is good practice. Varnished cambric and paper insulations are suitable for central stations and distribution cables, but their use in water and sewage plants is not advised for circuits of 2200 volts or less.

The covering of the insulation should be carefully selected to meet conditions of mechanical abrasion, oil or other chemical exposure. "Neoprene" is highly successful except for high temperature locations, and is now widely used as the outer covering of insulated wires and cables.

FLOW MEASUREMENT

FLOW IS quantity in movement past a point in a specified interval of time. Velocity is rate of linear movement in an interval of time. Velocity or some function of it is a fundamental factor in flow measurement; all common measuring devices are based on this concept.

Rate of flow is the measurement of quantity in motion for a relatively short period of time.

Total flow is the total amount of liquid moved during a period of time; usually a day, month, year. Total flow equals average rate of flow multiplied by time.

Units of flow commonly used in water and sewage practice are cu ft per sec (cfs); gal per min (gpm) and mil gal per day (mgd).

Reasons for Flow Measurement

Rates of plant output as well as pressure in lines are important. Total plant production in a day, week, month or year help chart trends for future planning. Rates of operation and output of individual operating units aid in proper operation and maintenance of filters, pumps, wells, wash water service, chemical feeders, electrical equipment.

Determination on efficiency of plant and unit operations and control of unit operations are also functions of flow measurement. Flow measurements are made to ascertain quantity of water sold and amount of non-revenue water; to determine the costs of operation, and to provide records of permanence.

In a sewage works the reasons for flow measurement are made to provide data and information on plant operation; to determine plant operating efficiency; to control unit operations, sewage and sludge flow, digester operation, sludge disposal, chemical feeding, etc. to determine operating costs; and to provide permanent records of performance.

Metering Points

In water works points of flow measurement include:

Source of supply—Letdown from reservoirs, raw surface water intake, raw water pump discharge, wells and well field output.

Treatment—Flow to or from coagulating basins and settling or softening basins; wash water to supply tank; wash water to filters; effluents from filters, finished water to clear wells.

Distribution—Transmission mains; high service pump discharge, elevated tank storage; booster pump discharge; interconnections to other supplies; consumers services.

Plant Water Supply (inside and outside), oil, gas and electricity.

In sewage works points of flow measurement includes:

Sewers—Main sewers, Interceptors, Tributary, lift stations, sampling stations.

Primary Treatment—Plant influent, bypass, sludge.

Disinfection—Chlorine, water for chlorination.

Secondary Treatment—Trickling filter influent, dosing tanks, sludge from clarifiers, recirculation.—Activated sludge influent, return sludge, waste sludge from clarifier, air volume, ratio of air to sewage and return sludge to sewage.

Sludge Digestion—Raw sludge, digested sludge, supernatant liquor, gas, heating water, recirculation.

Sludge Disposal—Volume handled, sludge dewatering, elutriation, chemicals, etc.

Plant water, portable water, oil, gas, electricity.

Devices for Flow Measurement

Head-area meters are used only for open channel flow or flow in partly filled pipes. They operate on the principle that a constriction or barrier in the flow channel will back up the liquid creating a high level (or head) than the level below the barrier; this head is a function of velocity and therefore rate of flow. Head-area meters include weirs, measuring flumes (Parshall flume) and open-end nozzles.

Functional meters are mechanical devices which measure some function of volume in movement and by means of other mechanical devices convert that measurement into rate of flow or total flow.

Functional meters include: (1) Differential head devices (Venturi tube, insert nozzle, orifice, Dall flow tube, Gentile flow tube); (2) Velocity meters; and (3) Pitot Tubes.

Pumps are not generally used but reciprocating pumps of controlled output may be used; centrifugal pumps are not good metering devices.

Displacement meters operate on the basis of the fill and draw principle. Meters for household services are usually of this type.

Miscellaneous devices for flow measurement include: the constant differential meter or rotameter; and inertial flow meters.

Selection of Primary Units

The devices which measure the flow are called primary units; devices which indicate, totalize or record flows are called secondary instruments.

Considerations which affect the selection of primary units include: Type of service, engineering factors, installation factors, accessories, comparative characteristics, and operators convenience.

Engineering factors include allowable permanent head loss, size of constriction, differential head, distance to secondary unit, type of transmitter; types of ends, corrosion resistance, etc.

Comparative considerations include: Accuracy, cost, capacity, range, permanent head loss, life expectancy, freedom from field tapping, freedom from upstream disturbances, ability to handle liquids containing solids, ability to handle pressure, laying length, and ease of installation.

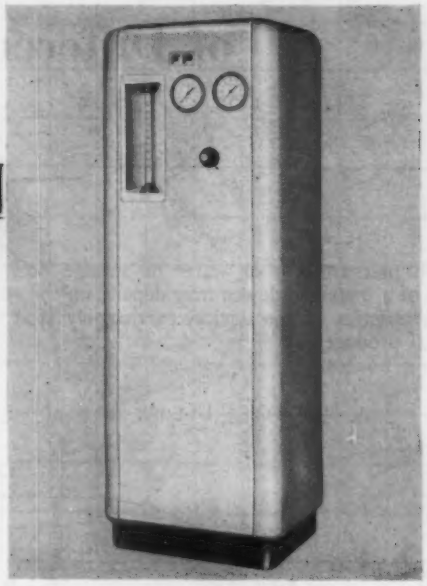
Operating Problems

Foreign bodies such as bricks, rocks, concrete, lumber, grease, jute, etc. have been found in primary devices. Any foreign matter in a primary unit will adversely affect the accurate operation of flow measuring devices. The remedy is to remove the material.

Negative head exists in metering instruments under certain conditions of installation and adversely affects the proper reading of the secondary instrument.

A knowledge of the construction, operation and adjustment of equipment, plus proper tools, spare parts, and a preventive maintenance schedule are essential factors in insuring against costly breakdowns. A sound maintenance schedule will include arrangements for a regular visit of a factory trained service man.

CHLORINATION AND INSTRUMENTATION EQUIPMENT



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Recovery Characteristics of Differential Producers*

IN THE measurement of water or sewage flow, the choice of a metering device may depend on the recovery characteristics of the device, particularly if it is a differential producer.

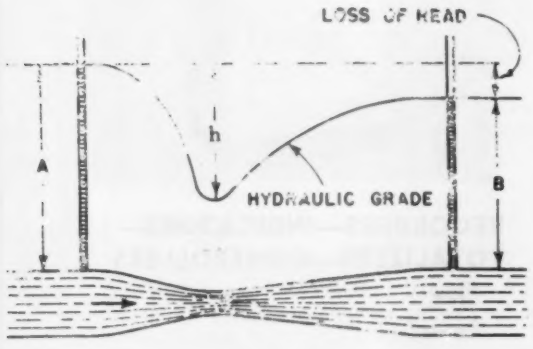


Fig. 1. LOSS of Head

When fluid passes through a differential producer, the line pressure downstream from the differential producer is less than at the inlet (See "A" and "B" in Fig. 1). This difference in pressure is called *loss of head* and is an important consideration in many installations. A high loss may result in inadequate line pressure at some distant point, or in high pumping cost, or in additional expense to elevate water for a gravity distribution system.

RECOVERY CHARACTERISTICS

Fig. 2 shows a comparison of head loss for differential producers commonly used for insertion in a pipe line. This graph is unique in that head loss is plotted against a capacity constant, β^2K, thereby permitting a comparison of primary devices of same inlet size but differing throat sizes which meter identical flows at identical differential pressures. The term β expresses the ratio of throat diameter to inlet diameter while the term K is a combined factor which includes the effects of jet contraction, velocity of approach, velocity distribution and friction. Values in Fig. 2 were obtained by measuring the difference in head between two piezometers, one located one diameter upstream from the differential producer, the other located five diameters downstream, and subtracting the ordinary friction losses in six diameters of pipe. Fig. 2 shows that the Dall Flow Tube and the Venturi Tube have much lower head loss than the orifice plate or conventional flow nozzle (Type A) when metering a given flow at a given differential.

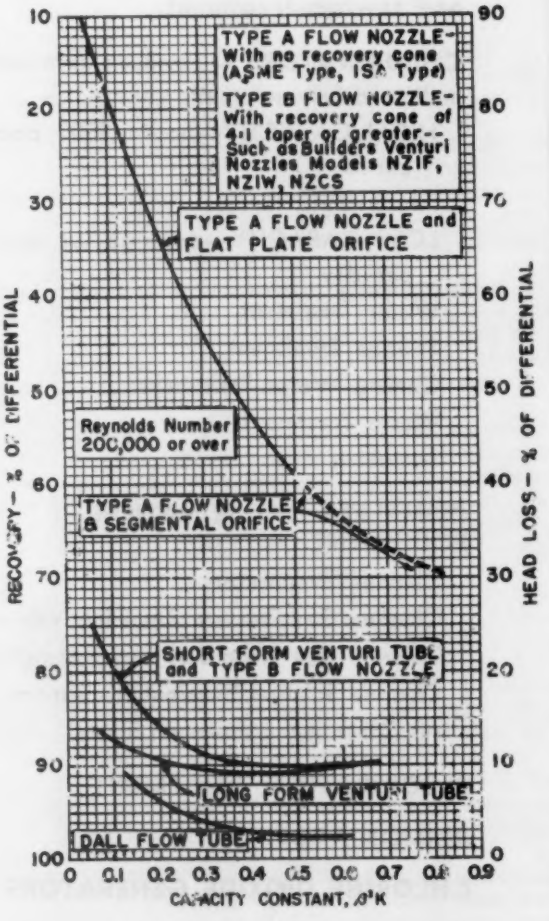


Fig. 2. RECOVERY Characteristics of Differential Producers at Equivalent Capacity

TYPICAL CALCULATIONS

To compute the loss of head, it is necessary to determine β^2K, which can be obtained from the following formula:

*Reprinted from Keep Sheet No. 3A of B-I-F Industries, Inc.

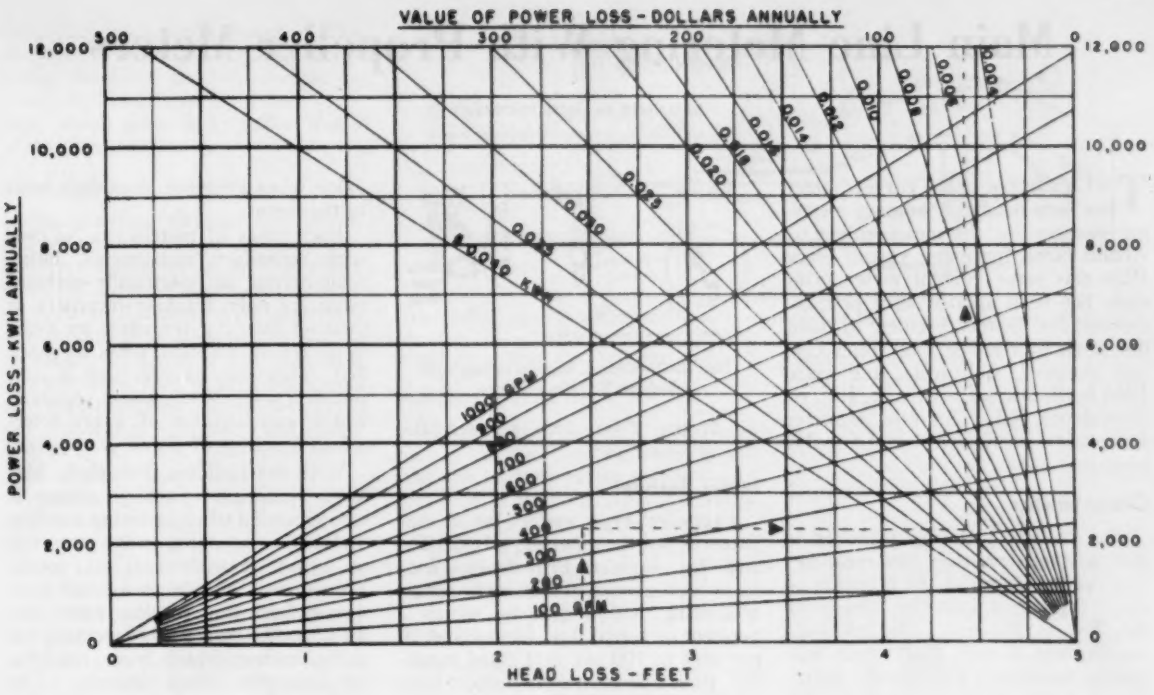


Fig. 3. GRAPH of Annual Power Cost for Various Head Losses

$$\beta^2K = \frac{Q \times 0.1764}{d^2 \times \sqrt{h}}$$

where:
β^2K = Capacity Constant Factor
Q = rated meter capacity, gal/min (water at 60°F)
d = diameter of pipe line in inches
h = differential in inches of water at rated capacity

Knowing β^2K, the head loss, expressed as per cent of differential, can be determined from Fig. 2 for any desired differential producer. To compute head loss at any selected rate of flow, multiply the differential at that rate of flow by the percentage which applies. A complete example is worked out on the next page.

Figure 3 provides a quick means for computing the value, in dollars per year, of power consumed due to head loss, or conversely, the saving due to head recovered, assuming 70 per cent overall pumping efficiency. Starting with a known head loss, read vertically to the proper rate of flow, then horizontally (to the right) to applicable cost per KWH, and then vertically upward to the annual value, in dollars, of power lost or saved.

If the pumping rate is higher than 1000 gpm (the maximum rate on the graph), divide the pumping rate by 10 or 1000 and proceed as directed, multiplying the answer by the same factor.

For example, assume that a differential producer designed for maximum differential of 80 in. is to be installed in a 12 in. line where maximum flow will be 3900 gpm.

From the discussion on the front of this sheet:

$$\beta^2K = \frac{3900 \times 0.1764}{12^2 \times \sqrt{80}} = \frac{3900 \times 0.1764}{144 \times 8.944} = .534$$

From Fig. 2, with $\beta^2K = .534$, the head loss with a Dall Flow Tube is 2.5 per cent of the differential, or since the differential is 80 in., the head loss is 2 in. of water.

For equivalent capacity, at the same differential, Fig. 2 shows that an orifice plate installation (segmental orifice required for this high capacity) would have a head loss of 39 per cent of differential. The loss with the orifice plate, then, is 39 per cent of 80 in. or 31 in. of water. With a Dall Flow Tube, head loss is less than for the orifice by 29 in. or 2.42 ft of water.

With 24-hour pump operation at 3900 gpm (70 per cent overall efficiency) and power cost of $.025 per KWH, the graph in Fig. 3 shows the annual cost of power which can be saved by selecting a Dall Flow Tube for the primary device rather than an orifice plate amounts to $560 (Use difference in head loss of 2.42 ft and 390 gpm rate on graph and multiply answer by factor of 10).

The suitability of a particular differential producer for a given installation depends not only on pressure recovery but also on numerous other factors. Technical data and information on all factors concerned with the selection of any type of differential producer may be obtained from the manufacturer.

Main Line Metering With Propeller Meters

by JAMES M. MONTGOMERY
Consulting Engineer, Pasadena, Calif.

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for many years. Since 1924 this same current meter principle has been applied as a primary element for the measurement of main line flows by the Sparling Meter Co., Los Angeles, California, and since 1944 by Builders-Providence, Inc., of Providence, R.I. This type of meter has proven itself well suited for this purpose.

Characteristics

The current metering principle is well adapted for main line measurement as the action of the propeller is solely dependent upon the velocity of the flow in the line. The pressure requirement is only that which will always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6-in. and larger does not exceed 6 inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section, keeping the propeller free from incrustation and preventing solids, which might damage the propeller, from entering the pipe line. The plastic propeller has proven itself well suited for this purpose, as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted either in a cast iron, steel,

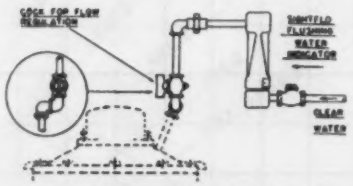


Fig. 1—Continuous flushing system with Builders Sightflo indicator

or bronze tube with a liner and straightening vanes.

Meter Features

Propeller type meters as manufactured by the Sparling Meter Co., and by Builders-Providence, Inc., have high accuracy over wide range, measuring within plus or minus 2 per cent of actual flow from about 10 per cent to 100 per cent rated capacity. Both manufacturers' meters have an "open upper limit" or temporary overload range, where the meters will continue to register with good accuracy at rates up to at least 150 per cent of rated capacity. Both the Sparling and the Builders meters are self-contained and self-operated, requiring no mercury, pressure piping or electrical connections; they are as easy to install as a valve or fitting with no adjustments required in the field.

One feature of the Builders Propeloflo Meter is the Venturi design. This produces an increased and consequently more stable velocity at the point where the fluid acts on the propeller. This increased velocity also produces added power, which is of value when applying secondary units to the meter.

Both types of meters can be used with secondary instruments, either cable-driven or electrically-operated totalizers only, totalizer-recorders or totalizer-indicator-recorders for nearby or remote location, when so specified. They may also be used in conjunction with electric alarm registers, where measurement of a pre-determined quantity of liquid is required.

With the Builders, Propeloflo Meter a continuous flushing system is recommended when metering the flow of liquids containing gritty materials or heavy concentration of solids. This system introduces a small continuous back flow of clear water into the propeller hub, thus preventing the solids-bearing liquid from reaching the propeller shaft bearing. The Builders Sightflo Indicator in this system gives a visual indication that the back flow is adequate and is properly maintained. (See Fig. 1)

The Propeller

The propeller type meter, as illustrated in Figs. 2 and 3, is made up of a 6-blade propeller, approximately 8/10 of the internal pipe diameter mounted transversely in the center of the pipe. The propeller is made of plastic material, having a specific gravity of approximately 1, and is suitable for use in either cold water or hot water, up to 250° F. For special liquids the plastic propeller may be replaced by an aluminum propeller, or stainless steel propeller,

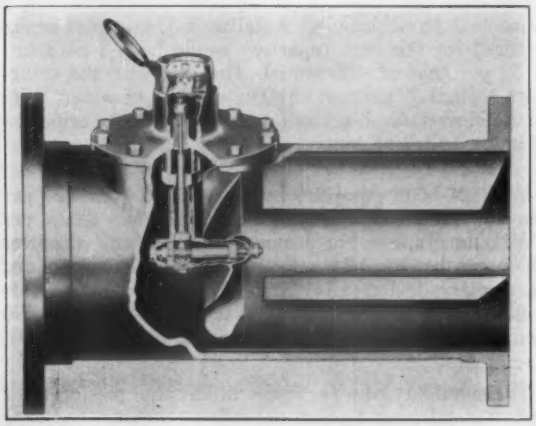


Fig. 2—Cutaway view of Sparling propeller meter
(Note the flow-straightening vanes)

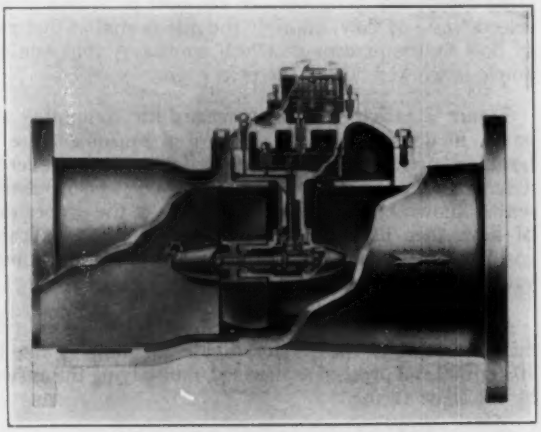


Fig. 3—Cutaway view of Builders Propoloflo meter
(Note the Venturi design and streamlined nose of propeller mechanism)

depending upon requirements. The propeller, when made of plastic, practically displaces its own weight in water and is mounted on ball bearings, which allow it to rotate freely in the stream of water.

Installation

The metering element may be installed directly on an existing pipe line by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined and the meter properly centered. In all installations the meterhead may be removed from the pipe line very quickly and easily, and it is normally good practice to make a yearly inspection.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiraling or jet action, is required for accurate results. The spiraling effect which may be caused in the flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use, but a very simple and effective correction may be made by the installation of 3 vanes, each approximately ⅓ the pipe diameter, and 2½ pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially opened gate valve, but are effective for double elbows or other standard fittings, and with such vanes the manufacturers state that the meter element may be installed with but five pipe diameters of straight approach. However, when possible, a longer section of straight approach is desirable.

A straight run of one pipe diameter downstream from the meter is normally sufficient for all installations. It is always good practice to use the straightening vanes. When the metering element is installed complete with either a flange or bell and spigot tube, straightening vanes are mounted directly inside this metering section to constitute a complete unit, ready for installation.

The metering element may be installed in either a vertical or horizontal pipe and it may be mounted on either the suction or discharge side of a centrifugal pump. In all cases it is required that the line run full.

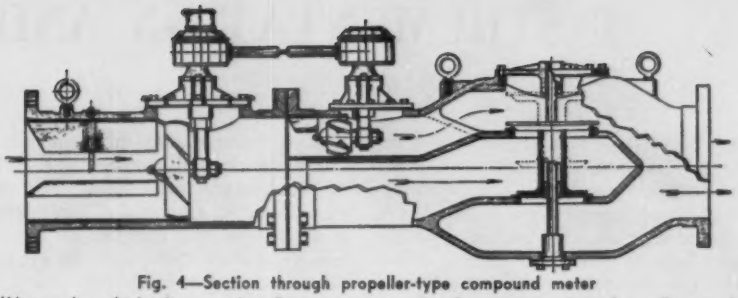


Fig. 4—Section through propeller-type compound meter
(Note valve which closes on low flows to cause entire flow to pass through small meter.)

Standard Specifications

The American Water Works Association has published standard specifications for cold water meters—current type, propeller-driven—known as No. 7M5-T. These cover general description, capacity, size, design, connections, operating mechanism, and notes of special importance.

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of ½ linear foot per second. The index, or number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

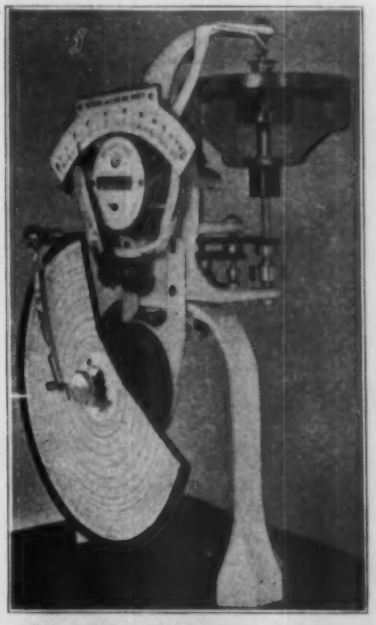


Fig. 5—Typical Sparling indicator-recorder of the mercury governor type

Compound Design

Fig. 4 is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. This is offered by the Sparling Meter Co., of Los Angeles, and has a range of 150:1. A compound unit consists chiefly of two propeller type meters working in series through a pair of ratchet clutches, allowing the meter revolving at the highest speed to drive the totalizer-register. On a very low flow the large meter will under-register, and thus allow the small meter to drive the totalizer. As the flow increases a pipe velocity is reached where the large meter has come in step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

Although the minimum flow is considerably above that of the standard domestic *compound* meter, it is well adapted for main line measurement as the pressure loss caused by the entire unit does not normally exceed 2 pounds at maximum flow.

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a current type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step.

INSTRUMENTATION AND CONTROL

SECONDARY instruments (or receivers) are devices which convert information sensed by and transmitted from a primary measuring device into observable information. Controls are devices which will receive information sensed by a primary unit and convert it into a control of some mechanical device, operation, or function, such as pumping, chemical feeding, flow regulation, filter washing, etc.

Secondary instruments (flow, level, pressure) are classified in two ways: Type of information desired, and method of transmission from primary to secondary unit. There are three types of information obtainable from secondary instruments, and these are obtainable either separately or in any combination. They are: Indication at the moment (as flow rate, level, pressure, temperature); totalizing over a period (flow); recording a drawn record on a chart as continuous indication of rates of flow, level, temperature and pressure. These secondary instruments are called respectively indicator, totalizer, and recorder.

Transmission

Secondary instruments are also classified according to method of transmission of information from primary unit to instrument. These are mechanical, electrical, or pneumatic. (Pressure is usually transmitted hydraulically.)

Mechanical meters are activated by float or directly by differential pressure. Electrical transmission is used where the receiver cannot be located near the primary unit or for other reasons. Electrical transmissions may be Chronoflo (time-impulse type) or other variations, and is good for any distance. Pneumatic transmission, by a varying controlled air pressure ranging from 3 to 15 pounds, is useful at distances up to 1500 feet. It features a continuous signal and immediate responses.

Summation and Ratio Metering

Two or more flow rates of pumps, mains or filters may be added together to give a total of the combined flow on a single receiver. This addition is accomplished by means of a summator (electrical or pneumatic) which receives the several sensed data and transmits the sum of the individual data. Ratio transmitters can be used to receive two different flows and calculate and transmit the ratio to a secondary instrument. This device is used in activated sludge plants to determine and indicate or record the air/sewage ratio and the return sludge/sewage ratio.

Receivers

In flow measurement, the flow varies as the square root of the head in the primary device. The receiver is designed to convert this information into the desired units. Charts or scales may be of the square root type with the divisions spaced according to the square of the unit. Readability is best at the high end of the scale. Linear type receivers have scales and charts with divisions spaced equally. Accurate readability is obtainable at both ends of the scale.

Controls

Flow measurement can be used to provide control of flows, chemical feeding, proportioning, pumping, sampling. Mechanical, electrical or pneumatic means can be used for control purposes.

Filter effluent controllers are available in two designs, self-powered, direct-acting; and hydraulic cylinder operated. They are used to maintain a constant rate of filtering regardless of loss of head as filters become dirty. Wash water controllers are similar to filter effluent controllers and are used to control the rate of filter back washing.

Auto-central control is a centralized system which automatically controls the rewash cycle of filters in sequence and can be initiated manually or by loss of head in the filters.

Chemical feed can be paced proportionally to flow at a fixed dosage rate, or by programmed schedule, or by timed-cycle. Sampling can likewise be controlled according to proportional flow, program, or time-cycle. Reservoir and elevated storage can be controlled by float or pressure sensing devices which control pumping. Distribution system flow can be controlled according to a combination of pressure and flow rate. (Pressureflo system.)

Operating Tables and Panels

Secondary instruments, also called receivers, or gauges, may be mounted in several ways. Loss of head gauges, rate of flow gauges, sand expansion gauges, and controls for filter operations are usually placed in a filter operating table. Wash water, and summated flow gauges are often hung in the filter gallery.

In centralized control, filter gauges, flow gauges, pressure gauges, and other types of receivers are placed in a single panel along with switches and controls, all of which may be located in the superintendent's or operator's office.

In sewage treatment works, flow measurement, disinfection, sludge measurement, sludge digestion pumping and withdrawals, sludge dewatering, elutriation, flow ratio-metering, and weighing of vacuum dewatered sludge all employ instrumentation and control. As in a water works, instruments and controls are frequently located in centralized panels, either in the operator's or superintendent's office or some other central location.

In both water and sewage works, centralized control reduces the work load on operating personnel, improves controls of operation and reduces operating costs.

Selection of Instruments and Controls

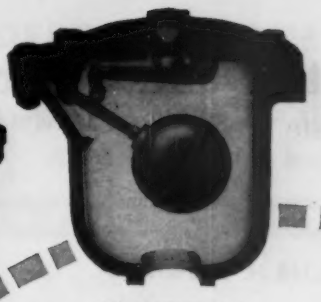
In the choice of secondary instruments there are a number of factors to be considered and many questions to be answered. In flow measurement, the type of primary device selected (weir, Parshall flume, Venturi tube, Dall flow tube, nozzle, orifice, etc.) dictates the method by which the secondary instrument or control is operated. The range of maximum to minimum flow must be known.

Accuracy depends not only on the primary device and the receiver but on the particular combination chosen. The relative location of primary device and secondary receiver has a bearing on the type of transmission used.

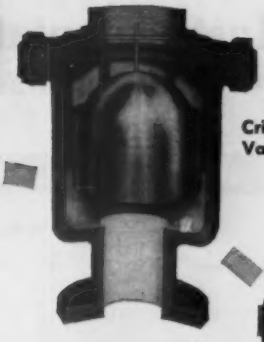
Choice of secondary instruments depend also on type of information desired, capacity of present plant, future capacity, and life expectancy of the equipment. Choice of primary and secondary instruments also have a bearing on control systems selected.

Selection of control systems and devices depend on the function, equipment, or operation to be controlled as well as the primary device, secondary instrument and system of control desired.

Crispin Midget Valves

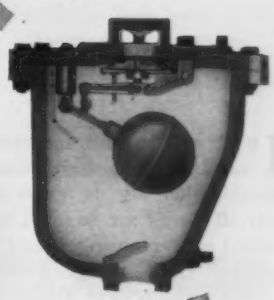


Crispin Pressure Valves



Crispin Air & Vacuum Valves

Crispin Universal Valves



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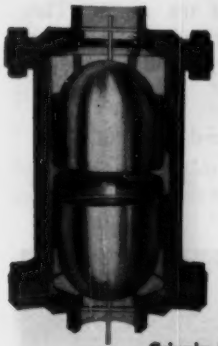

Crispin Negative Pressure Valves

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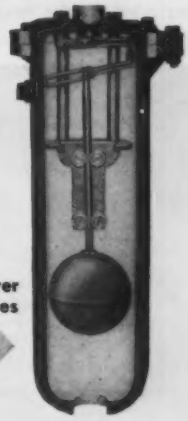

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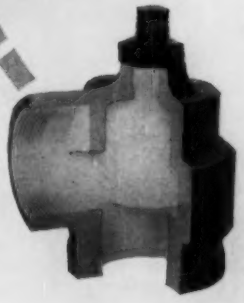
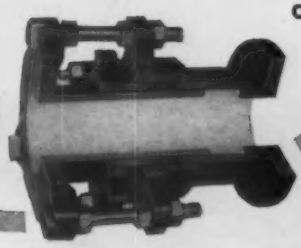
Crispin Deep Well Valves



Crispin Slip Joint



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Instrumentation and Control
in waste treatment

by WALTER H. BROWN

Project Engineer, Builders-Providence, Inc., Division of B-I-F Industries, Inc., Providence, R. I.

In all of the unit treatment processes for sewage and waste treatment, either liquids, gases or solids (or all three) are handled, moved or stored in some manner, and in every process, reasonably complete and accurate measurement (metering) and control is essential to obtain maximum operating efficiency and minimum cost of operation. No operator of any such process can be assured that operation is proper unless he knows the conditions under which the process functions.

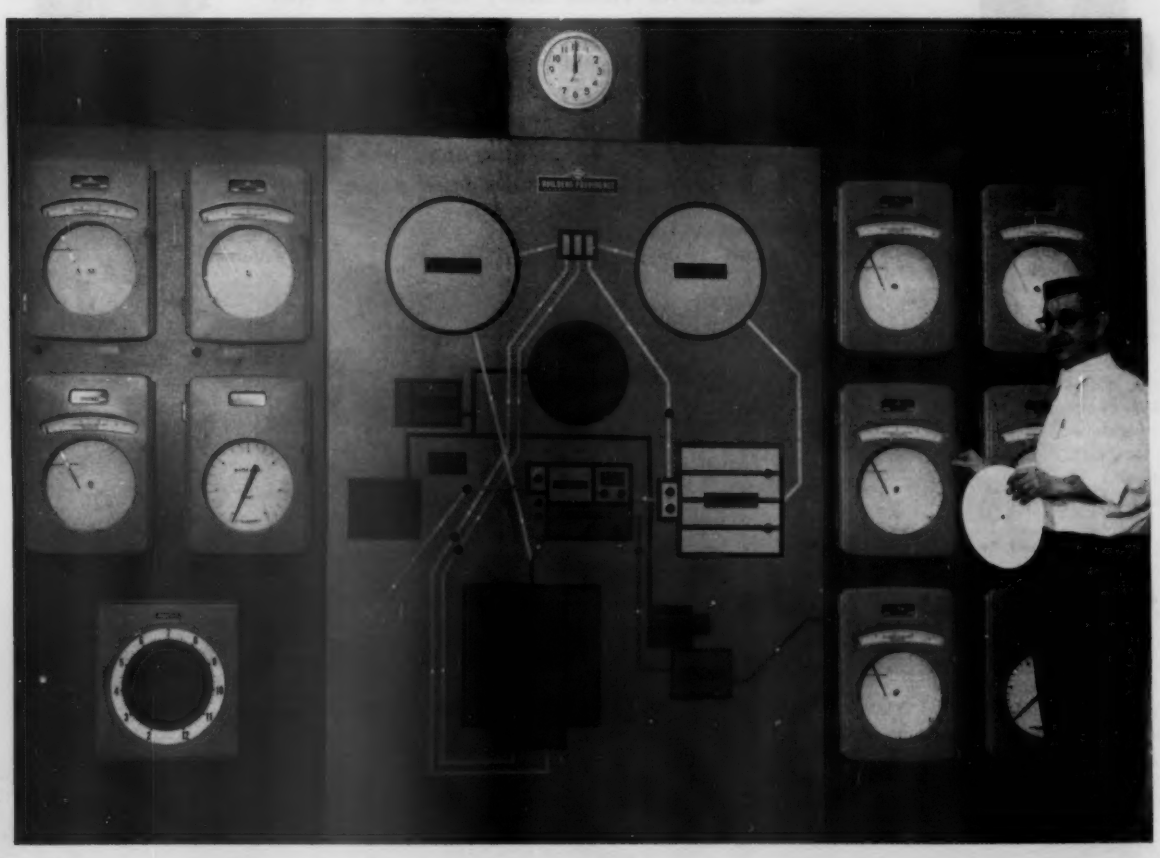
Included in the several unit processes of treatment applied to sewage and waste treatment are the following:

Screening
Sedimentation
Flocculation & Sedimentation
Flotation
Chemical Coagulation & Sedimentation
Neutralization
Chemical Oxidation or Reduction
Aerobic Biological Oxidation
Anaerobic Digestion
Filtration
Dewatering
Drying and/or Incineration
Lagooning
Chlorination

Table 1 shows the equipment, and general types of instrumentation and controls used in sewage and waste treatment processes. In addition to these processes used in sewage treatment, sewage works often have water pumping stations and boiler plants as integral parts of the works. They, also, utilize instruments and controls common to those particular operations.

Reasons for Instrumentation and Control

Reasons for instrumentation and control vary from the simple measure-



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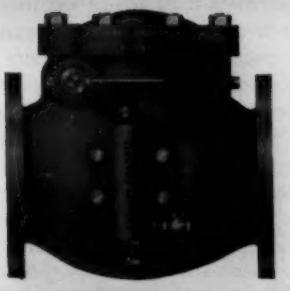
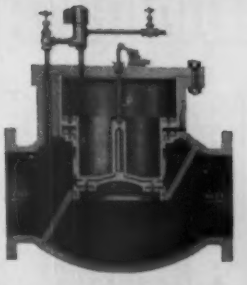
CUSHIONED CHECK VALVES



Swing Check Valve

Cushion chamber on side of body cushions only on last 5% of stroke, prevents any hammer or shock when closing.

Bulletin W-1



Electric Check Valve

Opens only when pump comes up to speed, closes automatically with pump running and shuts down pump when 95% closed.

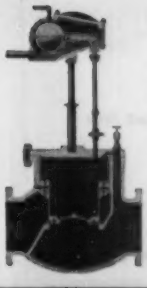
Bulletin W-10

ACCURATE WATER LEVEL CONTROLS

Altitude Control Valve

Maintains water level in elevated tanks within a variation of 3" to 12". May be installed underground.

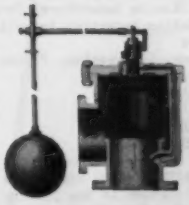
Bulletin W-4A



Cold Water Float Valves

Self-contained float maintains water level in tanks and reservoirs within ½" to 1" variation.

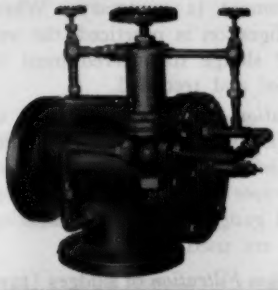
Bulletin W-5



Maintains liquid level control in open tanks, coagulating bins, etc. For high pressure service.

Bulletin W-5

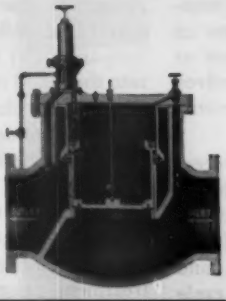
SENSITIVE PRESSURE REGULATORS



Surge Relief Valve

Protects water lines against excessive pressures caused by surges in the system. Fast opening—slow closing.

Bulletin W-2



Water Pressure Reducing Valve

Maintains uniform predetermined delivery pressure regardless of variance in upstream pressure.

Bulletin W-3A

ONE MAN CONTROL VALVES

Flowtrol Valve

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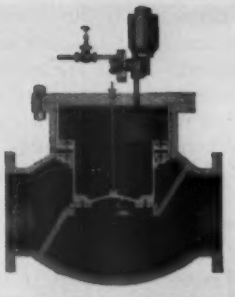

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Descriptive bulletins—numbered under each valve illustrated above—contain complete technical information. Write for your copies.

Table 1

Equipment Used in Unit Treatment Processes

UNIT TREATMENT PROCESS	Class or Type of Equipment										
	Special (See Notes)	Chemical Feeding	Flow Measurement	Mixing (Rapid)	Operation Control	pH Control	Proportional Pacing	Pumping	Tanks (1)	Temperature Control (2)	Weighing
Salvage		x	x	x	x	x	x	x	x	x	x
Screening	14		x		x			x			x
Sedimentation	15		x		x			x	x		
Flocculation & Sed.	11		x	x	x	x	x	x	x		
Flotation	12	x	x	x	x	x	x	x	x	x	
Chem. Coagulation & Sed.		x	x	x	x	x	x	x	x		
Neutralization		x	x	x	x	x	x	x	x		
Chem. Oxidation-Reduction	6	x	x	x	x	x	x	x	x	x	
Aerobic Biol. Oxidation	3-4		x		x	x		x	x		
Anaerobic Digestion	5		x		x	x		x	x	x	
Filtration	10		x		x			x	x		
Dewatering	8	x	x	x	x	x	x	x	x		x
Drying and or Incineration	9				x					x	x
Lagooning	13	x	x		x			x			
Chlorination	7	x	x	x	x	x	x	x	x		

NOTES:
1 - Reaction, Sedimentation, Storage Tanks, etc.
2 - Heating Systems, Heat Exchangers, Temp. Rec.
3 - Activated Sludge, Trickling Filters, Oxidation Ponds
4 - Air Blowers, Air Diffusers, Air Flow Measurement, Mechanical Aeration
5 - Mixers, Heating Equipment, Gas Collection
6 - Aerators, Chlorine Dioxide Generators, Ozonators, Reducing Agents, Redox Control, Oxidation Reduction Potential (ORP)
7 - Chlorine Gas Feeders
8 - Chemical Conditioning, Elutriation, Filter Press, Vacuum Filters, Sand Beds
9 - Incinerators and Dryers
10- Sand or Pressure Filters
11- Mechanical or Air Flocculators
12- Vacuum or Fine Bubble Flotation
13- Includes Oxidation Ponds
14- Mechanical Screens, Grinders, Comminutors
15- Sludge and Skimmings Collectors and Sludge Pumping Equipment
(Special equipment inherent to the process may include several of the types of equipment listed, as accessory equipment.)

ment of quantities handled to the complex control of the ratio of two or more quantities of liquids, gases or solids. Some of the problems involved are briefly outlined in the following paragraphs.

Screening is a mechanical process for the removal of large particles of suspended matter; it may also involve weighing of material removed if that factor is important. Operation and control are generally on a time cycle basis.

Flocculation by mechanical means, or by air, followed by sedimentation is used where coalescence of fine particles to form settleable flocs is desired. If air is used, air-flow measurement and control in relation to liquid flow is effected by ratio controllers. Where mechanical flocculation is used flow measurement and control of flow to maintain proper detention time are used.

Flotation to remove suspended matter is practiced where the specific gravity of the solids is about that of water and where these solids can be caused to rise to the surface either under the influence of (a) natural buoyancy, (b) fine bubbles introduced into the liquid or (c) fine bubbles produced by desolution of dissolved gases under the influence of a vacuum.

Measurement and control of flow are important; important too are the measurement and control of air introduced, or of a partial vacuum, if used. In some industrial wastes, chemical treatment prior to flotation is practiced with controls of chemical feeders from pH recorder-controllers and/or from flow metering devices.

Chemical Coagulation and Sedimentation are less frequently used in sewage treatment than in industrial waste treatment, but wherever chemicals are used, accurate flow metering is required to automatically pace the chemical feeder dosage in proportion to the flow. Precise chemical feeding can result in saving, the cost of instrumentation, many times over. Too much or too little chemical can interfere with settling waste chemicals, or kill process bacteria.

Neutralization of acid or alkaline wastes is almost always controlled through pH recorder-controller systems connected with dry or solution chemical feeders and is particularly vital if biological processes are to be used.

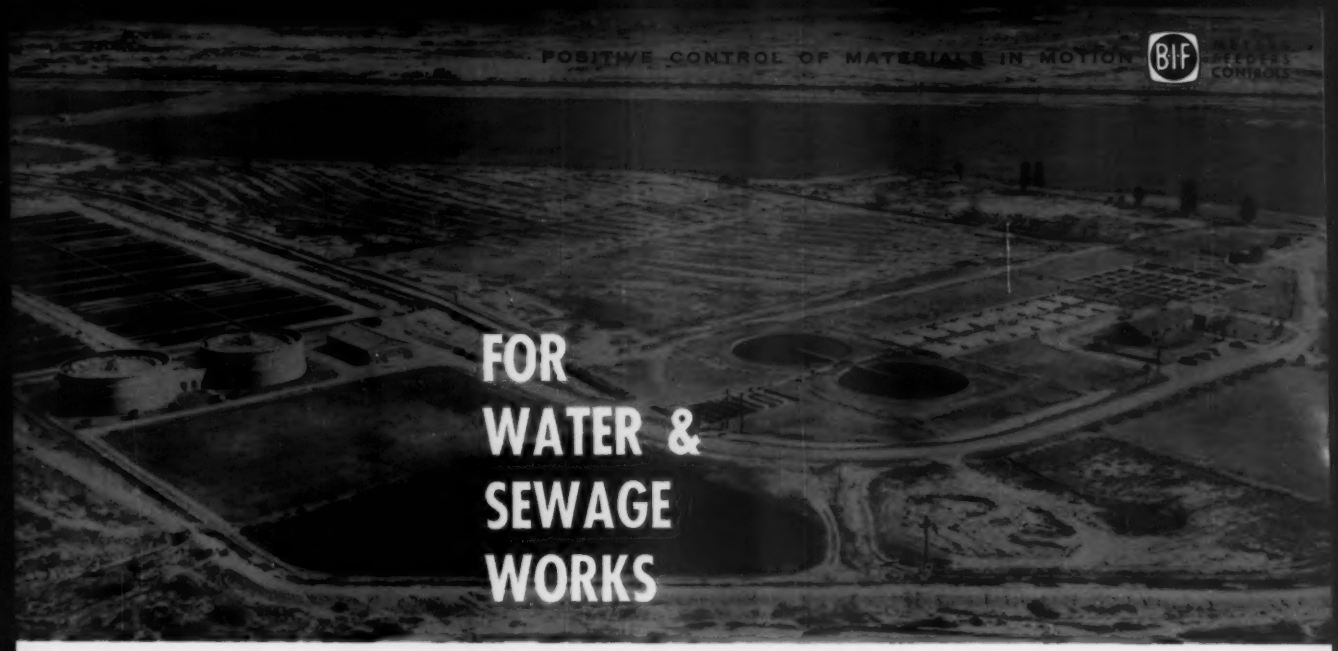
Chemical Oxidation or Reduction are processes used almost exclusively in the treatment of industrial wastes. Here pacing of chemical feeders in relation to flow may be accomplished by pneumatic or electrical control systems from primary flow measuring devices. In some instances, control of chemical feeders is from pH recorder-controllers or from ORP (oxidation recorder controllers) through electrical or pneumatic transmission of the information to proportioning weir boxes.

Anaerobic Digestion involves control of volume input, withdrawal of overflow liquor and digested sludge, temperature, and pH, all of which must be measured as well as controlled. Temperature control is most critical, but pH records indicate proper or improper operating conditions which are usually controlled by raw sludge input and digested sludge withdrawal or addition of corrective chemicals. Gas produced by digestion is a measure of operating conditions (as well as a usable by-product) and its measurement is necessary. Where stage digestion is practiced, the volume of sludge transferred must be measured and recorded.

Filtration through fine sand or gravel is practiced principally with certain industrial wastes in which instances rate of flow controllers, loss of head gauges and flow measuring devices are used.

Vacuum Filtration of sludges (raw, excess activated, digested) is commonly practiced in many plants where lagooning or other methods of disposal are not feasible due to the plant location. Such filtration calls for the automatic pacing of chemical feeders and bucket elevators as well as the control of the level in the vacuum filter tub.

Drying and/or Incineration of sludge is practiced in the larger plants where fertilizer is produced or where disposal of the ash presents a simpler problem than disposal of wet, dewatered or air dried sludge. Drying and/or incineration may take place in



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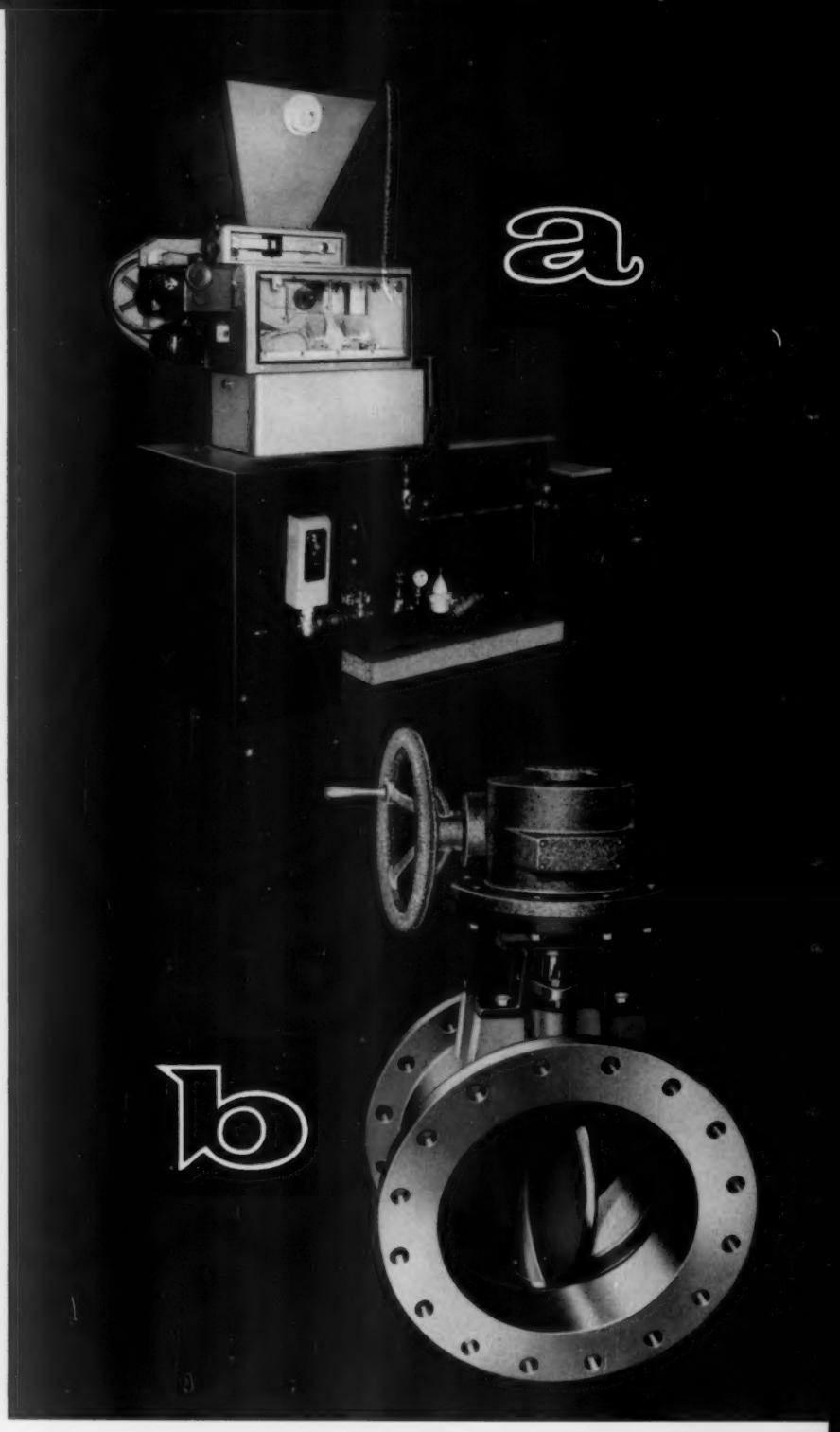

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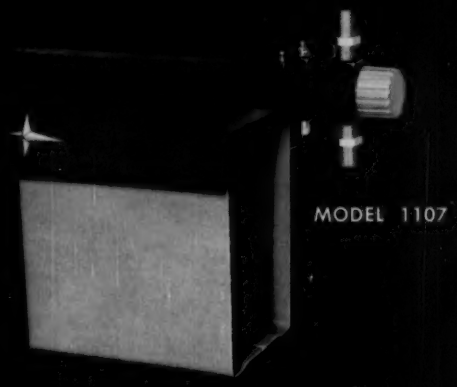

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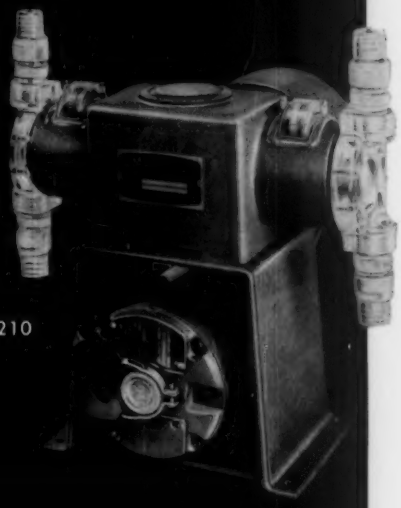

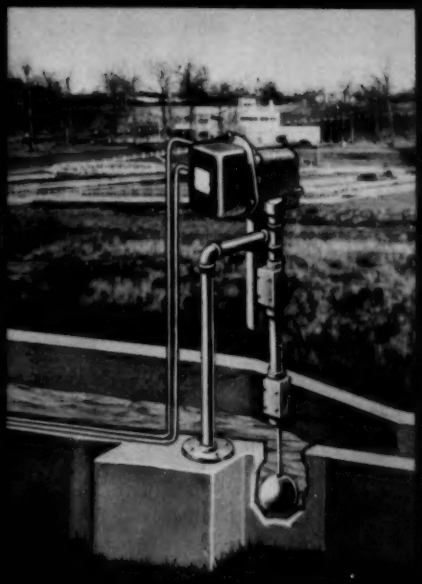

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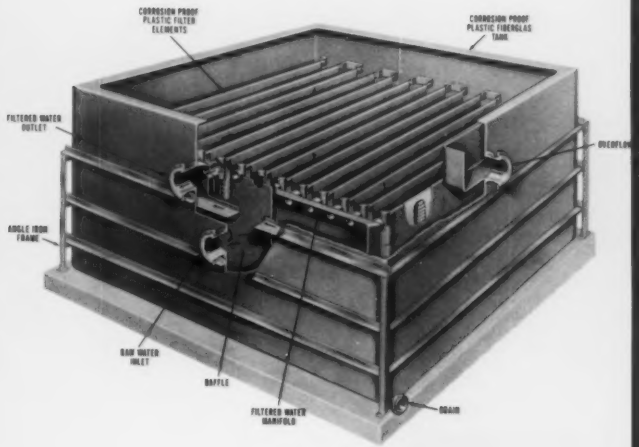

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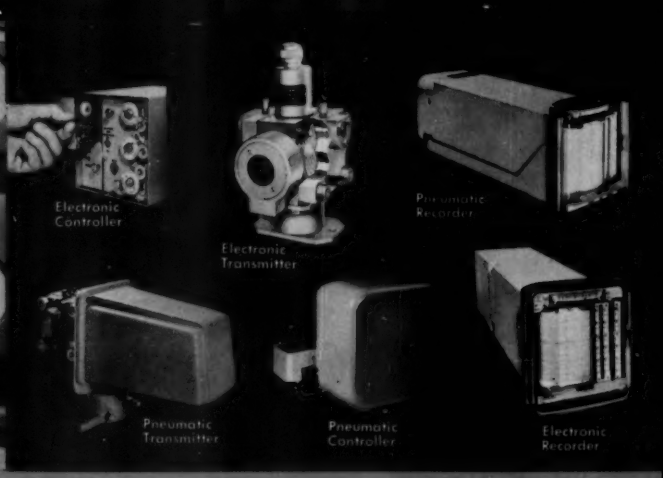

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Table 2

INSTRUMENTATION IN SEWAGE AND WASTE TREATMENT

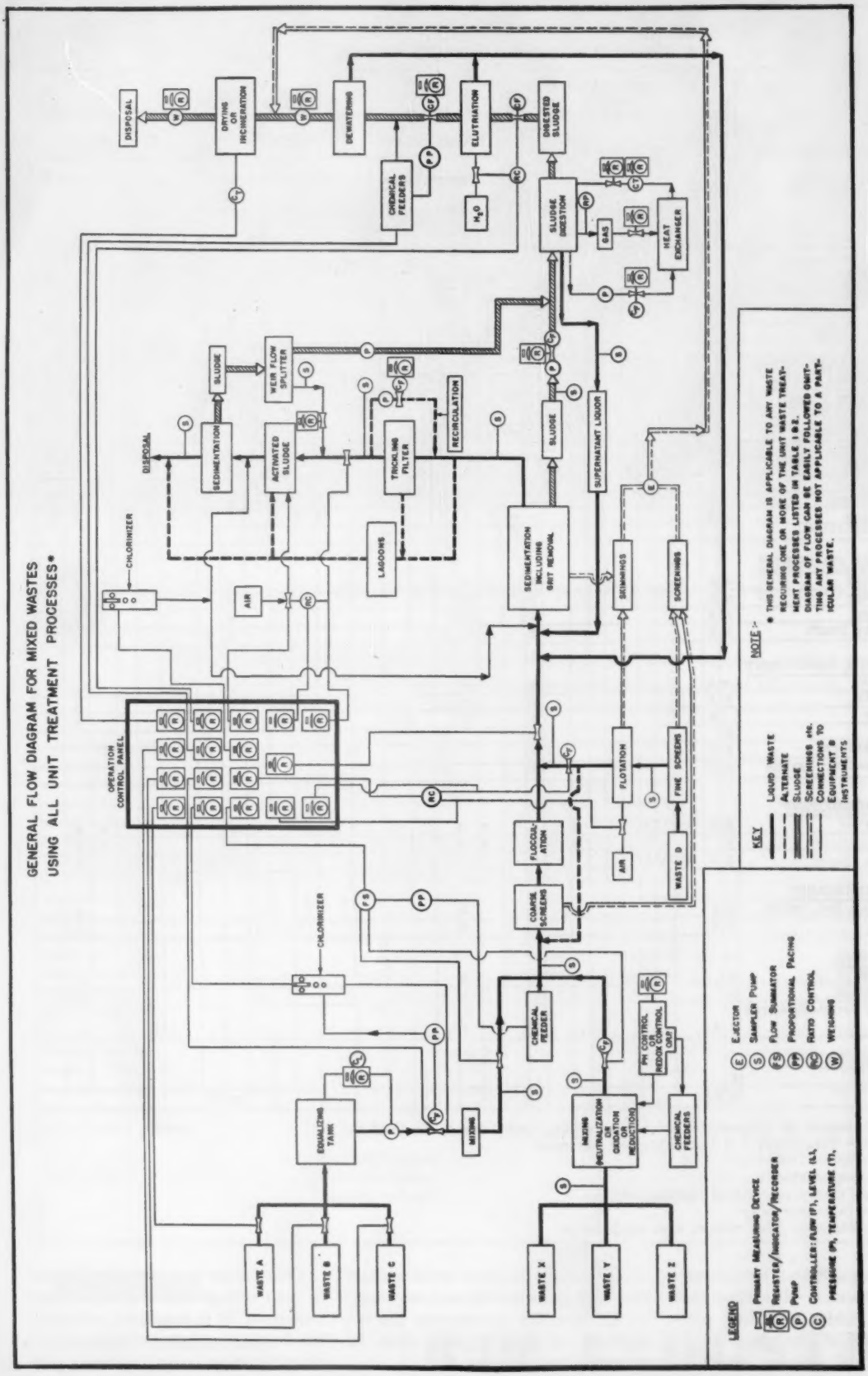
TYPE OF INSTRUMENTATION AND METER LOCATION	Municipal Sewage	Industrial Waste	PRIMARY MEASURING DEVICE: Open Flow Nozzle	Venturi Type[5]	Flume	Orifice	Propeller	Weir	Conveyor Scale	Displacement Meter	Gauge	Rotameter	RECEIVING INSTRUMENT *: MECHANICAL** Adjacent T	I	R	Remote[1] T	I	R	ELECTRICAL ** Adjacent T	I	R	Remote[2] T	I	R	PNEUMATIC ** Adjacent T	I	R	Remote[3] T	I	R
FLOW MEASUREMENT																															
Pumping Station	x		x	x									x	x	x							x	x	x				x	x	x
Plant Influent	x	x	x	x	x			x					x	x	x					x		x	x	x				x	x	x
Primary[3] Effluent	x	x		x	x			x						x									x					x		
Primary[3] Sludge	x	x	x	x									x	x	x							x	x	x				x	x	x
Aeration Air	x	x		x		x							x	x		x	x					x	x		x	x		x	x	
Return Activated Sludge	x		x	x				x					x	x	x							x	x	x				x	x	x
Excess Process Sludge	x	x		x				x					x	x	x							x	x	x				x	x	x
Recirculating Lines	x			x								x[4]	x	x	x							x	x	x				x	x	x
Digested Sludge	x	x	x	x									x	x								x	x					x	x	
Elutriation Water	x			x		x	x					x[4]	x	x								x	x					x	x	
Plant Effluent	x	x	x	x	x			x					x	x	x							x	x	x				x	x	x
Digester Gas	x	x		x		x					x		x	x									x	x	x	x		x	x	
Fuel Oil	x										x	x										x						x		
Electric Power	x	x										x		x	x								x	x					x	x
Chlorine Gas	x	x										x[4]	x	x	x				x	x	x		x	x	x	x	x		x	x
Chlorine Solution												x[4]																			
PRESSURE MEASUREMENT																															
Digester Gas	x	x									x			x									x						x	
Aeration Air	x	x									x			x									x						x	
Plant Water	x	x									x			x									x						x	
Incinerator Draft	x	x									x			x	x								x	x					x	x
TEMPERATURE MEASUREMENT																															
Digester Gas	x	x									x			x									x						x	
Aeration Air	x	x									x			x									x						x	
Plant Waste		x									x			x									x						x	
Raw Sewage	x										x				x									x						
Sludge Digesters	x	x									x				x									x						
Digester Heating System	x	x									x				x									x						
WEIGHT MEASUREMENT																															
Filter Cake	x	x								x			x	x								x	x					x	x	
Grit	x									x			x	x								x	x					x	x	
Chlorine	x	x	(Scale)																				x	x						x	x
LEVEL MEASUREMENT																															
Miscellaneous Wet Wells	x	x									x			x								x						x		
Digester	x	x									x			x								x						x		
RATIO GAUGES																															
Air - Sewage	x										x			x								x						x		
Sludge - Sewage	x										x			x								x						x		
Elutriation Water-Digested Sludge	x	x									x			x								x						x		
MISCELLANEOUS																															
Rainfall	x										x																				
pH	x	x									x												x	x						

Notes:
* Actuated by transmitter of corresponding type, where required
** T = Totalizer; I = Indicator; R = Recorder
1 - Up to 1800 ft.
2 - Any distance
3 - Primary or initial sedimentation
4 - Indicator only
5 - Magnetic flow meters also applicable

either a multiple hearth furnace or a flash dryer furnace. In either case, instruments include recording pyrometers at multiple locations.

Lagooning of sewage, waste or sludge usually involves nothing more than flow measurement and recording, except that this presupposes the occurrence of sludge which must be measured and disposed of.

Chlorination is an important process in both sewage and industrial waste treatment. It is employed principally for disinfection, but it also is used for its oxidizing and odor destroying pow-



GENERAL flow diagram for mixed wastes using all unit treatment processes.

er and to control activated sludge bulking, to prevent trickling filter ponding and to control trickling filter flies and sludge digester foaming.

Chlorine is commercially supplied as a liquefied gas under pressure. After being vaporized, it is generally fed under vacuum in a chlorine feeder which precisely governs the feed rate and delivers a chlorine solution to the point of application. Control of chlorine feeders may be by manually set rates but modern practice is to pace the feeder automatically according to sewage flow rate, or in accordance with a pre-established program. Pacing of chlorine feeders may be done from Venturi tube, Telemeter or summation units. Supplementary instruments used in conjunction with chlorine feeders include those which record the rate of flow of the chlorine feeder and those which record loss in weight from containers on weighing scales.

Flow Diagram

In the accompanying flow diagram, instruments and controllers are indicated at the various locations of any system which would involve *all* of the unit treatment processes listed above. In general, the left half of the diagram represents processes used in the treatment of industrial chemical wastes; the right half of the flow diagram generally applies to the treatment of domestic sewage and organic industrial wastes. To determine instrumentation and controls for specific wastes or sewage simply cross out any processes which do not apply or are not to be used and the proper flow diagram for that waste or sewage will be apparent.

Instrumentation

Table 2 lists the functions of instruments in sewage and waste treatment plants and the various points where instrumentation is desirable together with the most commonly used differential producers and primary devices. Available types of meters and functions are given; the combination used is generally a matter of choice dictated by the specific installation. The functions tabulated in Table 2 are not necessarily the only ones applicable to any given condition but represent those most commonly used. The differential producers and various types of meters are described hereafter.

Table 3

Control in Sewage and Industrial Waste Treatment

AUTOMATIC CONTROL OF	AUTOMATIC PROPORTIONAL	STEP[1] ON-OFF	TIMER[2] ON-OFF	PROGRAM[3]	LEVEL ON-OFF
Pumps - Waste		x			x
" - Sludge			x	x	
" - Recirculating	x	x		x	
Chemical Feeders	x	x		x	
Clarifier Mechanisms			x		
Samplers	x	x		x	
Grit Chamber Mechanisms			x		
Grit Washers			x		
Screens			x		
Chlorine Gas Feeders	x	x		x	
Tank Levels					x
Alarms					x
Ratio Gauges	x				

Notes: 1 - In step with pumping or flow rates
2 - In accordance with predetermined time cycle, fixed rates
3 - In accordance with predetermined program, variable rate

Flow Meters provide information on the volume of sewage or waste, the volume of sludge withdrawn from settling basins, the amount of air supplied, the amount of return sludge, etc. This information is invaluable in the determination of unit loadings and efficiencies which are desired for maximum detention times. Orifice type meters are definitely not recommended in sewage works because of the suspended matter in the liquids handled and the high non-recoverable head loss. Flow meters, particularly of the Kennison or open flow nozzle type, are also used to measure the flow of industrial wastes into municipal sewers, particularly where charges for sewer service to industry are based on volume of waste discharged.

Pressure Recorders provide visible evidence of aeration diffuser clogging. Prompt cleaning means that excess power costs will be avoided. Pressure recorders are also useful to indicate digestion tank gas pressure, gas burner supply pressure, process water pressure, etc.

Level Recorders are used in sludge storage tanks, etc.

Temperature Recorders are used, not only on the digestion tank contents but also on the digestion tank heating system. Some localities prohibit the discharge of wastes to sewer system or streams above a maximum temperature. Temperature recorders provide the local authorities with a record of the effluent temperature.

Controllers

Table 3 lists various equipment which can be automatically controlled by a variety of standard methods. Chlorine gas feeders, chemical feeders, samplers and recirculating pumps can be *automatically* paced by means of electrical or pneumatic transmitters which send out impulses in direct proportions to the flow. In addition to the above units, waste sludge and recirculating pumps can be controlled in steps according to tank levels or by means of switches in flow instruments.

Timers, which provide on-off contacts, can be utilized for control of sludge and recirculating pumps, and sedimentation tank, grit chamber and screen mechanisms. This equipment is used where rates and time intervals of operation are fixed and the cycle repeated.

Program Devices are available for control of sludge and recirculating pumps, chlorine gas feeders, chemical feeders and samplers. These program controllers are extremely useful where a variable rate is required and can be predetermined; the program is variable but repeats after a definite time cycle.

Simple On-Off Level Switches can be used for control of waste pumps, screen mechanisms, maintenance of tank levels, and alarm systems.

Summary and Comment

In sewage and waste treatment, experimentation and study of process

operation is highly desirable. To make such experimentation possible, it is necessary that measurement and control of all variables be possible, which means complete instrumentation and control are essential in order to ascertain the facts of operation.

Several types of industrial waste treatment processes provide varying decrease of purification and material reclamation. These processes require instrumentation and control for efficient operation.

The choice of particular treatment processes, either for sewage or industrial wastes, depends on the individual waste and on local conditions. Each problem needs individual study and engineering design, which means that instrumentation and control as well as treatment process are designed for the patricular problem. Variations of the above-mentioned standard control systems can often be engineered by the several water and sewage instrument manufacturers.

It is extremely desirable to provide instrumentation and control units designed especially for several decades of life and for which repair parts will be available over that period.

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Time Recorder-Totalizers

at Sewage Lift Stations

by GEORGE W. WELSH, JR.

Deputy Chief, Bureau of Operation, Dept. of Public Works, Baltimore County, Md.

The Baltimore County Department of Public Works has within its jurisdiction sixty sewage pumping stations. Pumps range from 4 inch to 12 inch in size and have capacities of from 100 GPM to 7,500 gpm. At a few of these stations venturi meters have been installed. The installation of a magnetic recorder is planned for one of the newer stations.

The Bureau needed a method of collecting information on operating and maintenance costs for each of the sixty units as they related to total pumpage. A monthly record of cost verse pumpage was desired.

The Standard Instrument Corp. manufactures a Time Recorder-Totalizer designed primarily to monitor the efficient use of men and machines in industry. Plant or office production is surveyed by this equipment which records the time and frequency of machine, process or system operation and computes the total "on" time chronologically on tape. The Time Totalizer can be furnished to register in hours or tenths of hours; or in minutes and tenth of minutes.

The Baltimore County Bureau began experimenting with this equipment in an effort to obtain data from which station pumping costs could be determined. Figure 1 shows an installation of wall mounted controls and recorders at a very old station. Figure 2 shows a newer face mounted control panel with recorder and a section of the control center.

Basically, The Time Recorder-Totalizers are installed the same at each station. An extra set of contacts is placed in the starter. Power is picked up from the most convenient source and wired through a fused switch for protection. The starter contacts signal each operation of the pump to the recorder.

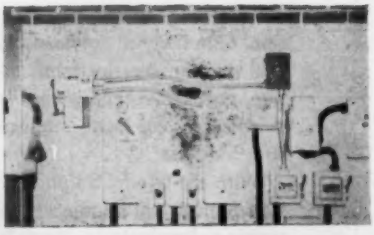

FIG. 1—WALL-MOUNTED controls and Time Recorder-Totalizer.

The stations, which are automatically operated, are visited only once daily by the attendant. He registers the number of operations of the pumps shown on the counter of the Time Recorder-Totalizer and resets the counter to zero. The values are registered daily and submitted to the office monthly. The chart-roll is also received at the office and from the combination of the two, the computations and checks are made. To determine the actual discharge rate of the pumps, a draw-down test is made at each of the stations.

Although the results obtained are not as accurate as those provided by venturi meters and equivalents, the values computed present a fair approximation of the flow through each station. These data enable the bureau to correlate operating costs at the various stations and provide the information necessary for establishing an effective maintenance program.

FIG. 2—Left: FACE-MOUNTED control panel with recorder. Right: Section of control center showing Time Recorder-Totalizer.

Chlorine Handling and Storage

by EDMUND J. LAUBUSCH

Sanitary Engineer, The Chlorine Institute, Inc.,* New York, N. Y.

Consideration is given in the following discussion to several important physical and chemical characteristics of chlorine that relate to its safe handling and use. Basic built-in safety devices common to all chlorine containers are reviewed and additional design recommendations are highlighted based on the experiences of a number of producers and users of chlorine. Although certain situations may warrant modified or additional procedures, the following are fundamental to the operation of most chlorination facilities. The reader is referred to the *Chlorine Manual*[1] and similar documents for more detailed information.

Chlorine Containers

Liquid chlorine is packaged in steel pressure vessels of several sizes, all of which are registered with the Bureau of Explosives and subject to the Regulations and Specifications of the Interstate Commerce Commission. Loaded containers have about 12 per cent gas space at 68°F to allow for chlorine expansion at higher temperatures; this gas space becomes completely filled with liquid when the temperature exceeds approximately 158°F. Safety devices are provided on all containers.

In the sanitary engineering field 100- and 150-lb cylinders, one-ton containers (net), or tank cars usually are employed, the choice depending on chlorine requirements and other factors. All containers are intended for use by the consumer in delivering chlorine to process; intermediate, stationary storage is provided at a few locations, but the practice currently is not recommended for general use.[2,3]

Cylinders and Ton Containers. Fusible plug safety devices are provided on all cylinders and ton containers. They are designed to melt or soften between 158°F and 165° to preclude a build-up of hydrostatic pressure resulting from thermal expansion due to fire or other hazardous conditions. In the case of cylinders the fusible plug is part of the Chlorine Institute standard cylinder valve, and is located below the valve seat independent of the valve control (Fig. III-1). Ton containers are provided with six, larger plugs, three located at each end but *not* part of either the gas or liquid discharge valves (Fig III-2). These safety devices should never be tampered with under any circumstances.

Tank Cars. Welded steel tank cars —16-, 30- or 55-ton capacity—(Fig. III-3) have a special safety valve which consists of a breaking pin assembly and a spring-loaded safety valve. The safety valve is set to re-

*The Institute and its members make no guarantee of results and assume no liability, jointly or severally, in connection with the information herein contained or the safety suggestions herein made.

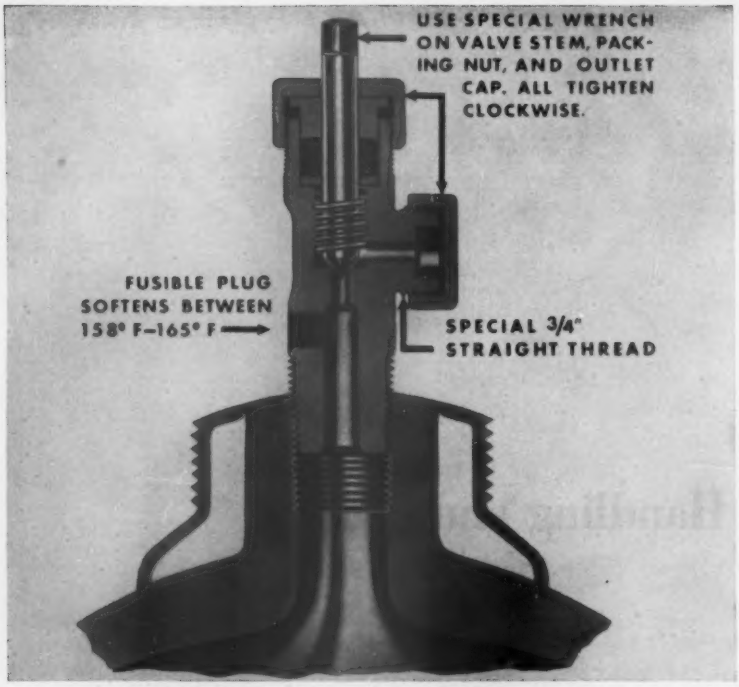
USE SPECIAL WRENCH ON VALVE STEM, PACKING NUT, AND OUTLET CAP. ALL TIGHTEN CLOCKWISE.
FUSIBLE PLUG SOFTENS BETWEEN 158° F–165° F
SPECIAL 3/4" STRAIGHT THREAD

FIG. III—1. STANDARD cylinder valve of Chlorine Institute with a poured fusible metal plug. Valves with screwed type plugs are also available. The Chlorine Institute ton container valve is similar but sometimes has a larger internal hole and contains no fusible plug.

lieve at 375 psig or 225 psig for cars registered to ICC Specification 105A500 or 105A300, respectively. (The relieving pressure is stenciled on the car.) This safety valve and four angle valves are the only connections on the car, and all are located in the car dome.

The two angle valves on the longitudinal axis of the car discharge liquid chlorine. Under these valves there are eduction pipes extending to the bottom of the tank, each having a rising ball excess flow valve designed to close when the rate of discharge exceeds about 8000 lb/hr such as might occur, for example, if the liquid discharge line should accidentally be broken. At right angles to these valves, perpendicular to the longitudinal axis, there are two additional angle valves for discharge of chlorine gas (Fig. III-4). All angle valve outlets have one-inch, American standard taper female pipe threads protected by one-inch plugs. (Fig. III-5) These plugs should always remain in place until connection is made and should be replaced immediately upon disconnecting the pipe line in order to prevent moisture from entering the valve and promoting serious corrosion.

Multiple Unit Cars. The TMU, or multiple unit tank car (Fig. III-6), consists of an underframe carrying 15 one-ton containers. It is especially suitable for installations where chlorine requirements are substantial and where more flexibility than that afforded by single unit tank cars is required.

Transfer and Storage

Shipping and Moving. Cylinders of chlorine may be shipped in any amount by motor and rail carriers but they almost invariably are received at water and sewage treatment plants by truck. In transit, cylinders should be positioned upright and securely fastened; ton containers should be fastened securely on a suitable rack, or other means should be provided to prevent rolling. If cylinders are to be unloaded from a truck to ground level it is good practice to have available a hydraulic lift gate or suitable skid with a rubber bumper at the bottom. Suitable hoists having a capacity of not less than two tons and fitted with a specially designed lifting bar (Fig. III-7) should be provided for unloading and handling of one-ton containers.

A suitable hand truck should be available for moving chlorine cylinders, and cylinders should be securely fastened thereon (Fig. III-8) at all times. Hoisting should be avoided as much as possible but, where necessary, a suitable lifting device should be provided.

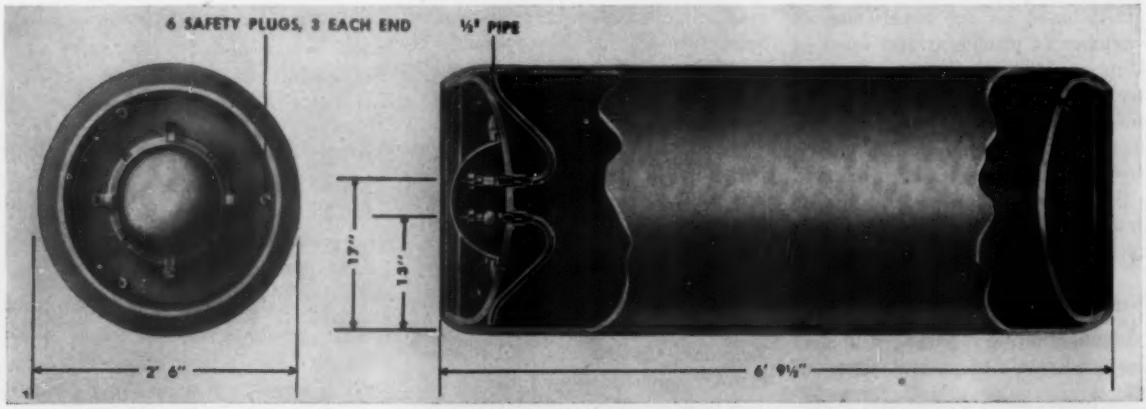

FIG. III—2. CHLORINE ton container, equipped with two valves connected to eduction pipes to permit either gas or liquid withdrawal. Note the location of the fusible metal safety plugs.

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W&T Series A-711 V-notch Chlorinator

The W&T Series A-711 Chlorinator features a new concept in chlorine flow control—the V-notch Variable-Orifice. This provides wide range adjustment and excellent reproducibility of chlorine flow with substantially linear flow readings on a rotameter feed rate indicator. The Series A-711 Chlorinator is adaptable to any type of chlorinator control. Corrosion resistant materials, which include fiberglass plastic for the chlorinator cabinet, are used throughout to assure long life and maintenance free operation.

W&T Series A-711 V-notch Chlorinator

W&T DIAPHRAGM PUMPS

W&T Diaphragm Pump

Chlorination of small water supplies involves problems which W&T Diaphragm Pumps are especially designed to meet. This equipment feeds hypochlorite solutions or other soluble treatment chemicals, and is furnished in three types:

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day.

Automatic Water Operated Diaphragm Pumps automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

WT SILACTOR®

The WT Silactor (pronounced SILL-actor) provides a system for the continuous production of activated silica with chlorine. Raw materials—chlorine and sodium silicate—are withdrawn directly from their own containers without handling or dilution. All chlorine used in the WT Silactor is available for the normal functions of chlorine, such as killing bacteria and algae, or for the oxidation of iron, manganese and other oxidizable material.

WT Silactor

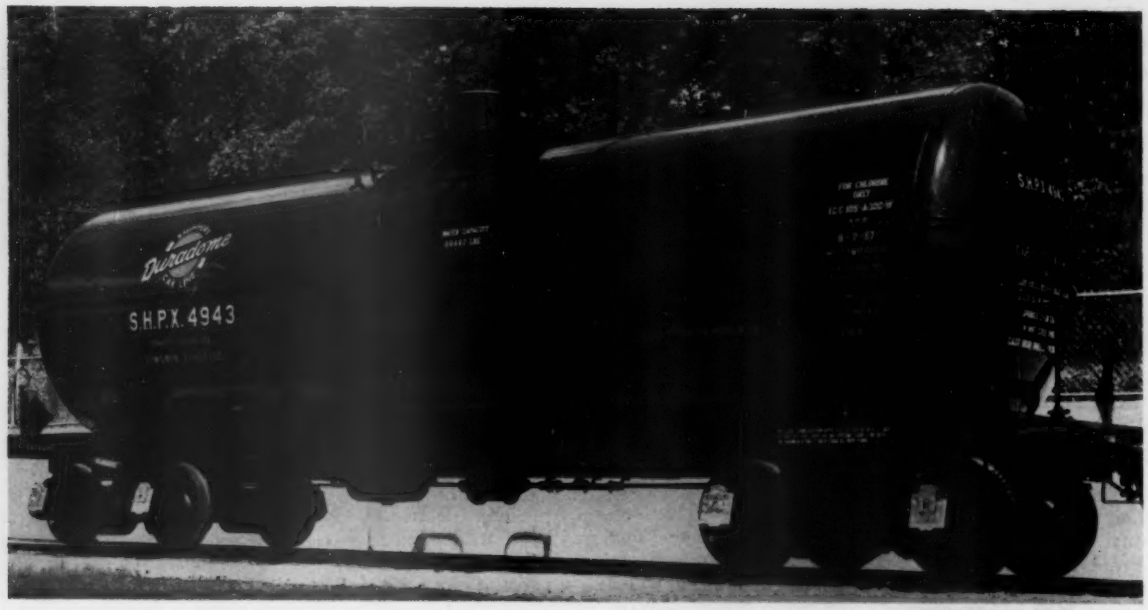
DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. Both volumetric and gravimetric weighbelt types are available. Dry feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from ounces per hour to 3000 pounds per minute, depending upon the equipment and chemical used.

CONVENIENCE

W&T is represented by a service staff prepared to discuss the proper equipment for any chlorination problem.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.



Courtesy of ACF Industries

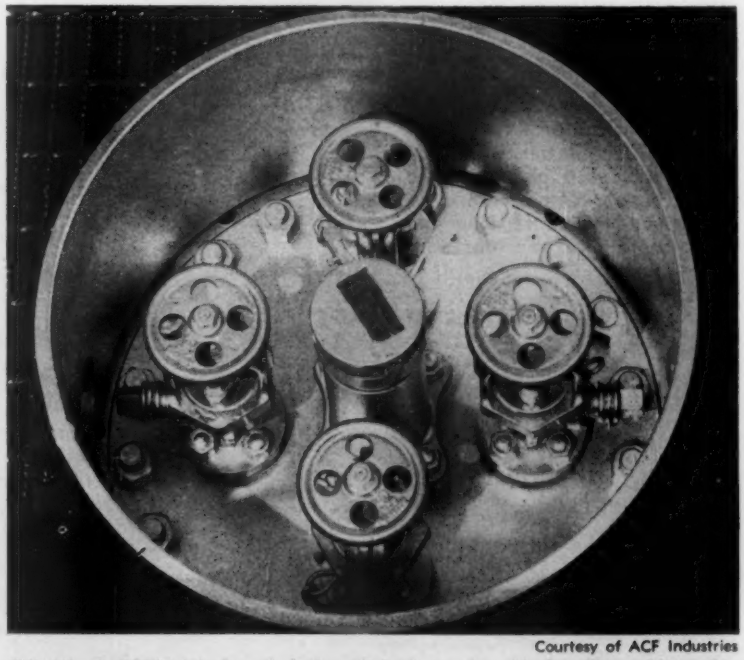
FIG. III—3. CHLORINE tank car, 55 ton capacity is made of steel and is protected by a 4-inch cork insulation and an outer steel shell.

Multiple unit tank cars can be consigned to an approved public railroad siding remote from the point of use and the containers trucked to their final destination. Single unit tank cars, however, may be consigned only to privately-owned or leased sidings.

Storing. Chlorine cylinders preferably should be stored in an upright position and so arranged that, in an emergency, a leaking container can be removed with the least possible handling of others. Ton containers should be stored on their sides at all times; they should rest securely on cradles or on a level rack equipped with adequate safety blocks to prevent rolling and slightly elevated from the floor to keep them dry (Fig. III-9).

Cylinders and ton containers always should be stored in a cool, well-ventilated area, protected against external heat sources. Good housekeeping should be observed in the storage area. If stored outdoors, protection from precipitation, direct sunlight, and other damaging influences should be provided. It is preferable to provide for separate storage of full and empty cylinders and ton containers and, except when in actual use, valve protection hoods always should be kept in place.

Chlorine storage and feeding areas preferably should be located above ground level, well ventilated, and of fire-resistant construction. For large installations, sub-surface installations, and in buildings occupied by persons or housing equipment subject to chlorine attack, a separate and reasonably gas-tight enclosure opening to the outdoors should be provided for housing the chlorine feeding equipment. The enclosure should be vented to the upper atmosphere and equipped with positive means of exhaust (near floor level, at the center of the room or opposite the entrance) capable of a complete air change within 2 to 3 min-



Courtesy of ACF Industries

FIG. III—4. DOME interior of single unit tank car for chlorine. The safety valve in center is surrounded by four angle valves for chlorine discharge. Check valves are located in eduction pipes under each of the two (liquid) angle valves along the longitudinal axis of the car.

COLUMBIA-SOUTHERN CHEMICALS FOR WATER AND SEWAGE TREATMENT

Liquid Chlorine—Rigid manufacturing supervision assures high purity. Shipments made from strategically located plants, in 15 ton multi-unit tank cars, and in 16, 30 and 55 ton single tank cars. Also in barges.

Pittchlor®—A dry, granular, free-flowing, highly stable calcium hypochlorite, containing a minimum of 70% available chlorine. Used for control of chlorine susceptible bacteria and algae. Special sewage treatment applications: reduction of B.O.D., elimination of odor, disinfecting of effluent discharge, and increase of coagulation.

Can be applied manually or mechanically. Packed in 100 lb. drums, and in 3¼ lb. and 5 lb. cans.

Pittabs®—Pittchlor in tablet form. Tablets are slow dissolving, and provide a prolonged release of available chlorine for up to 18 hours. Dust free, and can be applied manually or mechanically.

Packed in 100 lb. drums and 5 lb. cans.

Light Soda Ash—Free flowing, rapidly soluble. Na_2O equivalent of more than 58%. Shipped in bulk and in 100 lb. bags.

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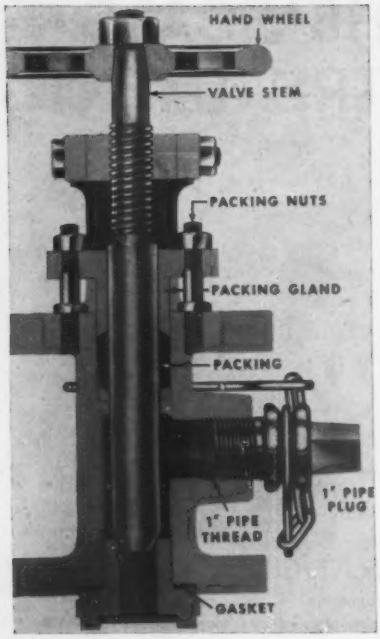

FIG. III—5. STANDARD chlorine angle valve for single unit tank cars.

utes. The actuating switch should be located immediately outside the entrance, and it is good practice always to effect a complete change of air before entering. A satisfactory ventilation scheme involves a combination fresh-air and exhaust system consisting of fans that force fresh air into the enclosure through openings near the ceiling and other fans that can exhaust any chlorine-contaminated air near floor level. The system should always be completely independent of any other ventilation system on the location.

Using

Facilities should be designed and operated to minimize all hazards associated with connecting, emptying and disconnecting chlorine containers. These operations should be performed only in well-lighted places by authorized personnel equipped with gas masks or other suitable respiratory protective devices. Whether discharge is in the liquid or gas state, the containers, discharge valves, and piping should be so located to avoid fracture from impact with heavy objects. Container valves should not be left opened when operating personnel are not immediately available at the plant. Recommendations more detailed than those that follow are available.[1,4]

Emptying Containers. Higher temperatures on chlorine containers than on chlorine gas pipe lines or chlorine feeders will cause liquefaction in the cooler portions of the line or in the chlorine feeder. Where possible, provision should be made for emptying containers in areas of about equal or slightly higher temperature to that in which they are stored (approximately 70°F-80°F preferred. A pressure reducing valve near the container may be necessary where it is not possible to obtain suitable temperature conditions. Similarly, provision should be made to keep liquid chlorine lines at a temperature somewhat lower than that existing at the chlorine source.

Chlorine gas is discharged from cylinders in an upright position; liquid chlorine is discharged from inverted chlorine cylinders but the latter practice is neither common nor recommended. Ton containers can be emptied in either the liquid or gaseous state. The container units always should be positioned so that the two valves are in a vertical plane; in this position, the upper valve discharge chlorine gas and the lower valve discharges liquid chlorine.

The maximum withdrawal rate of chlorine gas at 70°F approximates 40 lb/day for 100- and 150-lb cylinders, and 450 lb/day for ton containers. (Gas withdrawal from tank cars seldom is practiced.) The rate of discharge of liquid chlorine is considerably greater than that obtainable when discharging chlorine gas. Under no circumstances should heat be applied to any chlorine container to increase the withdrawal rate.

Manifold systems can be used to connect two or more chlorine cylinders or ton containers where the maximum chlorine feed rate exceeds the maximum continuous withdrawal rate from a single unit (Fig. III-10). When used, special safety precautions should be observed and the temperature of all manifold containers must be uniform. Liquid chlorine lines never should be manifolded.

The rate of discharge of liquid chlorine from tank cars depends on the tank car vapor pressure and temperature of liquid chlorine, and is limited by the excess flow valves to about 8000 lb/hr per valve. In general, unless an exceedingly high rate of flow is required, where the chlorine must be raised to an abnormal elevation, or where the air temperature is low, the car pressure ordinarily will pro-

Courtesy of Solvay Process Div., Allied Chem. Corp.

FIG. III—6. MULTIPLE unit tank car (TMU) for carrying 15 one ton chlorine containers. This type of delivery unit is available from all chlorine manufacturers.

chlorine

fast delivery on less than carload lots

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In 16-, 100-, 105-, 150-lb. cylinders and 1-ton tanks.

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Eliminate chlorine storage problems—get just the amount of chlorine products you need, *when* you need them, from Jones Chemicals! This will save you valuable storage space.

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SODIUM HYPOCHLORITE
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FLAKE CAUSTIC
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LIQUID CAUSTIC
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FIG. III—7. HOIST and lifting bar assembly for handling chlorine ton containers.

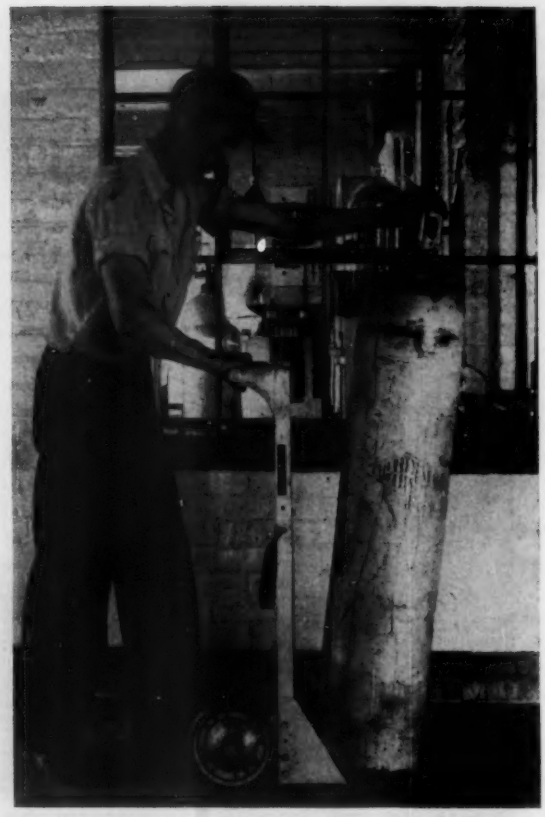

FIG. III—8. HAND TRUCK for moving chlorine cylinders. Note strap to secure cylinder during movement.

vide an adequate flow. Oil-free, thoroughly-dried, clean compressed air may be applied to the tank car to increase the discharge rate if necessary, or the car can be delivered with this padding provided. Special precautions must be observed by consumers who supply their own padding, and only a separate compressed air system should be used for this purpose. Recommendations concerning this operation are available from the Chlorine Institute.

Scales, preferably of the indicating type (Fig. III-10) should be provided for weighing the chlorine to ascertain the amount of chlorine remaining in containers at any time. The weight loss should be observed frequently, especially when approaching the point where the container is nearly empty. Chlorine gas pressure gages do *not* measure the volume or weight of chlorine remaining but merely indicate the probability of lowered tank contents. (Pressure exerted from confined chlorine gas is a function of temperature and, theoretically, one lb of chlorine will exert the same pressure as will 2,000 lb at any given temperature.) Evidence of a vacuum break, caused by lowering of pressure in the chlorine supply system, also might provide advance warning of depletion of the chlorine supply.

Connecting and Disconnecting. Connections to valve outlets on cylinders and ton containers can be made by either a clamp-and-adapter or a union connector. The clamp-and-adapter connection (Fig. III-11) is preferred. In making connections it should be ascertained that the outlet valve is closed

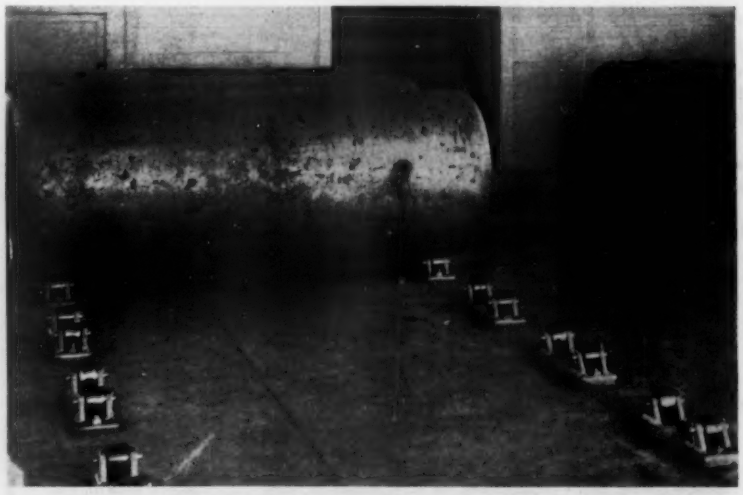

FIG. III—9. STORAGE of chlorine ton containers on cradles prevents rolling and elevates the container slightly from the floor.

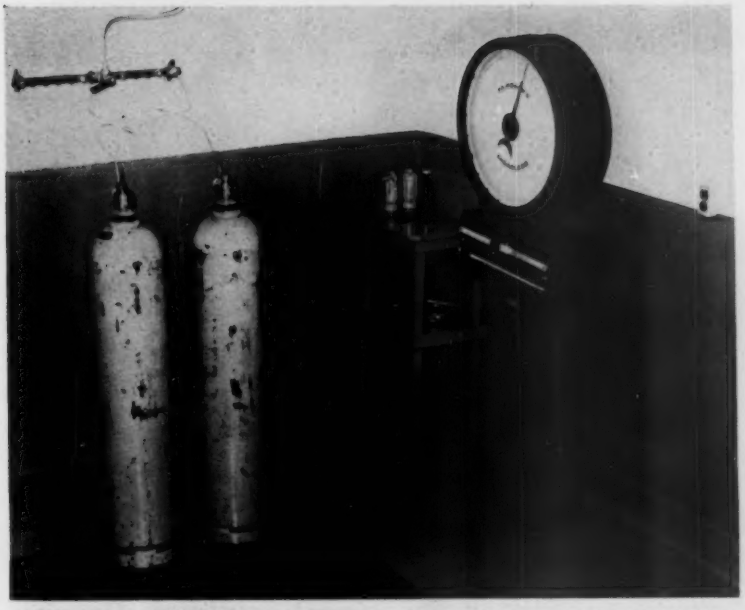

FIG. III—10. INDICATING scale for ascertaining cylinder contents and checking chlorine feed. Recession of platform eliminates cylinder lifting. Note cylinder manifolding and slope of flexible chlorine discharge line from cylinders.

before the outlet cap is (slowly) removed. Gasket surfaces should be thoroughly inspected and cleaned and a new gasket of standard material should be used. All chlorine cylinder and ton container valve outlets are the same and conform to American standard B57.1. Outlet threads on such valves are *not* taper pipe threads. Connections that do not fit should never be forced.

Cylinder and ton container valves should be opened *slowly* using a special wrench no longer than 6 inches for this purpose. One complete turn of the stem in a counter-clockwise direction opens the valve sufficiently to permit maximum discharge. An auxiliary cylinder or ton container valve (Fig. III-11) should be installed adjacent to the container valve between it and the chlorine feeder or gas header on manifolded systems. Such a valve serves as an emergency shut-off should the container valve leak. Moreover, it prevents chlorine gas from escaping from the supply line when the container is removed from service. In the interests of safety, the ventilation system should be operating whenever containers are being placed into or removed from service, and at all times when an emergency exists or adjustments and repairs are being made.

Tank car angle valves should be connected and disconnected (Fig. III-12) using a pipe wrench no longer than 18 inches. In discontinuing the flow of liquid chlorine from tank cars (and ton containers) the supply line to the evaporator should be emptied since expansion of any remaining chlorine may build up hydrostatic pressure and burst the line. The tank car angle valve (or lower ton container valve) should be closed first and the line evacuated by continuing the use of any chlorine remaining before the evaporator inlet valve is closed.

All containers should be tested for leaks when being placed into or removed from service. If a leak is evident around the valve stem and all other precautions have been observed, it usually can be eliminated by tightening the packing nut. Chlorine leaks *always* get worse; help should be solicted if they are serious and they can not readily be eliminated. (These matters are discussed in detail in the next article of this series.)

FIG. III—11. CLAMP-AND-ADAPTER or yoke connection of auxiliary cylinder valve. Note flexible tubing.

Other Appurtenances

Piping Systems. Chlorine can contribute to the corrosion of a system to which it is introduced. Dry chlorine, either liquid or gas, is not corrosive to steel or other common metals (except aluminum) at temperatures below 300°F. In the presence of even minute quantities of moisture, chlorine is highly corrosive. Accordingly, pipe lines, valves, containers and other equipment through which dry chlorine passes should be tightly closed when not in use to preclude the introduction of moisture from the air.

Dry chlorine gas or liquid under pressure should be handled in extra heavy wrought iron or steel pipe, or in flexible, annealed copper tubing suitable for 500 lb working pressure.

A flexible arrangement should be provided on the discharge line from the chlorine container and the piping should slope upward from the chlorine source, especially when discharging in the liquid state. Long piping lines should be avoided.

Moist chlorine is extremely corrosive and can not be handled in pipe or tubing of the same construction used for dry chlorine gas. For low-pressure conduction of moist chlorine gas or for aqueous solutions of chlorine, hard rubber, Saran-lined, rubber-lined, polyethylene, or Uscolite piping should be used. For higher pressures, materials such as silver, platinum or Hastelloy "C" should be used.

It is important to observe the correct temperature conditions in conducting chlorine from the source to the point of use. To prevent reliquefaction of gas, such piping systems and control equipment should be in an area at an equal or a higher temperature than that of the chlorine container. It is preferable to locate chlorine gas lines overhead through relatively warm areas than along the floor or in other areas where low temperatures may be encountered. For liquid chlorine piping systems, conditions which contribute to vaporization should be avoided. Lines should be as cool as or cooler than the chlorine containers and they should not be located in overheated areas where vaporization might occur.

For one and one-half inch pipe and smaller, connections may be either screwed, welded or flanged. If flanged, facing should be small tongue-and-groove. Gaskets should be 2-3 per cent antimony lead or asbestos sheet conforming to Specification MIL-A-1472; rubber gaskets are not suitable. Screwed fittings should be 3000-lb forged-steel construction.

Valves may be necessary at various points in chlorine piping systems to isolate sections of the system, to regulate pressure conditions, or to stop the flow of chlorine gas to a feeder when several are directly connected to the same chlorine supply. Valves should be drop-forged steel of a type specifically designed for chlorine service. (The Chlorine Institute standard ton container valve is useful in many situations.) While essential at many points, their use should be held to a minimum, especially on liquid chlorine systems.

FIG. III—12. CONNECTING chlorine tank car. Note flexible discharge line and special wrenches.

Evaporators and Feeders, Etc. Various types of evaporators and chlorine gas feeders are used at sanitary engineering installations and these will be discussed in detail in a later article in this series. Equipment should have sufficient capacity to exceed the highest expected demand at any time and to provide continuous, effective treatment under all prevailing hydraulic conditions. Duplicate equipment should be provided for disinfection and other essential treatment processes. Where this is not feasible a complete stock of spare parts and tools should be maintained for emergency replacements or repairs. For normal operation, emergency or stand-by equipment should not be depended upon to meet the chlorine demand or to satisfy chlorine requirements for the treatment employed. A reliable, uninterrupted supply of water, free of coarse suspended matter, should be available under adequate pressure to assure the continuous operation of solution-feed equipment. Hydraulically- or electrically-driven equipment, if needed to maintain a satisfactory working pressure, should be provided with alternate power sources.

Although chlorine is marketed in remarkably pure form (the concentration of impurities being far less than that which can be detected by ordinary assay procedures), various reports indicate that certain operating difficulties have occurred at some installations. Many of these are presumed to be caused by the occasional presence of minute concentrations of impurities in commercial liquid chlorine.* Although silicon halides, hexachloroethane, ferric chloride, carbon tetrachloride and others have been cited from time to time, the actual cause (s) of such difficulties has not been established. Moreover, limiting impurities concentrations have not been defined either alone or in possible cumulative or synergistic forms. Some research currently is under way from which it is hoped that qualitative and quantitative performance criteria might be defined. Meanwhile a program of routine inspection and maintenance of chlorine feeding equipment is recommended to minimize operating problems believed to be associated with commodity quality.

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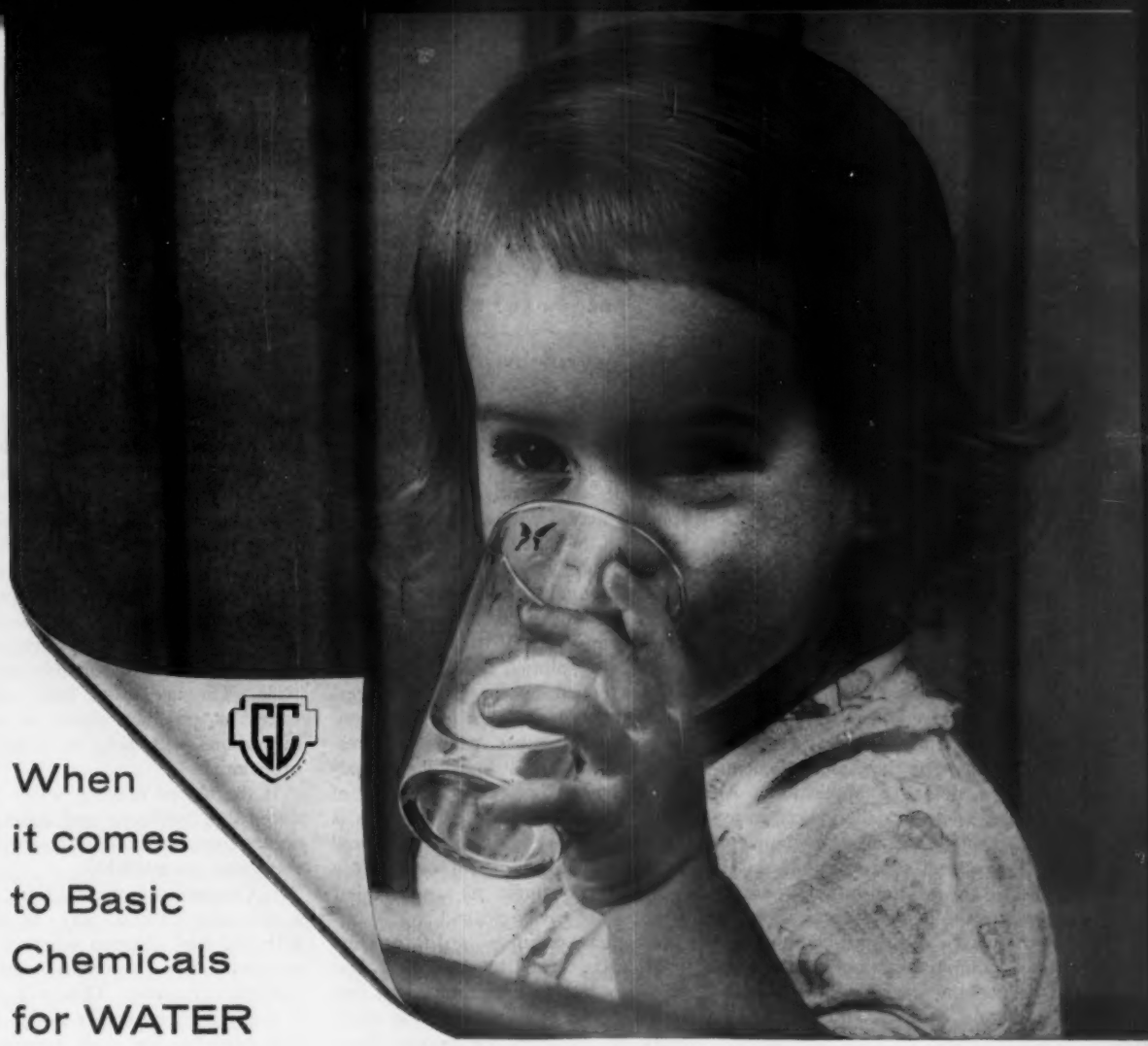
*The American Water Works Association recently published a tentative specification for liquid chlorine which limits the combined concentrations of all impurities to 0.5 per cent in accord with Federal practice[5]. Chlorine producers currently furnish a water works grade of chlorine of comparable or better quality.



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Efficient Design and Operation of Chemical Distribution Systems

By VIRGIL W. LANGWORTHY

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The design of machines to feed into water the chemicals required for proper treatment has been improved through the years by the application of sound engineering principles. Design has improved to a point where the selection of these machines, even for difficult or unusual functions, is routine.

There is, however, another important phase of the chemical-feeding operation which has not had the benefit of the same engineering approach: design and operation of the system which transports the dissolved chemical to a point of application. An advanced feeder installation can measure accurately and dissolve completely the required chemicals but this is useless if the solution cannot be transported to the point of application. It is the purpose of this article to review some common practices in the area of design and operation of chemical distribution systems and to suggest improvements.

Design

Lines which carry chemical solutions can fail in two ways: they can corrode and leak or they can scale and plug. These failures may be caused by either improper operation of the feeder or by inadequate design. Whatever the cause, replacement or repair will be required. Many present design practices, however, prevent this from being easily accomplished.

The most consistent oversight in connection with maintenance and replacement is the practice of burying chemical feeder lines instead of leaving them accessible. It may make a slight improvement in the appearance of the installation to have the lines hidden, but it makes them very difficult to repair.

If the feeder lines are accessible they should be flexible instead of rigid. Replacing flexible pipe is a much easier task because a rigid pipe is much harder to place in position. Also, if scaling occurs in a flexible pipe it may often be cracked off the inside of the pipe by bending and flexing.

The plugging of chemical feeder lines by scale is an important problem because a scaled line offers resistance to solution flow. Scaling can be postponed by the use of larger-diameter solution lines but if the conditions which cause scaling are present even the largest line will eventually become plugged. The use of troughs instead of closed conduits is an alternative design to avoid plugging. Scaling will occur in a trough if the conditions are right but troughs are easily cleaned.

Another common solution-line problem is caused by too long a line to the point of application. If a line is too long it often requires too much work to maintain the proper flow. This may be avoided by moving the chemical feeder closer to the point of application.

Solution lines are often installed in such a way that siphon conditions are created. This is not good practice but if it cannot be avoided provision must be made at high points in the system for venting trapped air.

Acid solutions may cause corrosion in feeder lines. A line through which acids are to be fed should be made of a suitable corrosion-resistant material.

Operation

Trouble can develop in properly designed and installed chemical feeders if they are not operated properly. When alkaline materials, such as lime or soda ash, are being fed improper operation can cause scaling of the solution lines. Alkaline scale in solution lines can occur in two ways: deposition of calcium carbonate. The lime or soda ash itself can also scale out because of supersaturation. This can usually be remedied by the use of more makeup water if adequate dissolving capacity has been provided.

If alkaline scale is caused by the precipitation of calcium carbonate there are alternative methods of operation which will help to prevent trouble. The reaction of the soda ash with the calcium in the makeup water may be one cause of this type of scale. The use of as little makeup water as possible—short of supersaturation—will help to solve this problem.

If the use of makeup water is reduced to a minimum and scaling still occurs three methods of treatment of the water are available:

1. Calcium carbonate sludge from a softening process may be mixed with the feed solution where it will accelerate the precipitation of the calcium carbonate. This will result in the formation of more sludge but it will minimize the scale forming on the walls of the solution line. The sludge in the line may be kept in suspension by increased turbulence and by maintaining a flow velocity of between 4 and 6 fps.

2. Ion-exchange softened water may be used as makeup water. This will prevent the formation of calcium carbonate by eliminating the calcium ion.

3. Polyphosphate complexing agents may be used to complex the calcium ion, thereby minimizing calcium carbonate precipitation and avoiding scale attachment to the wall of the solution line.

If these treatment methods cannot be utilized scale build-up can be controlled by using a "go-devil" cleaning device in the solution line. A go-devil is essentially an inflated ball provided with link-chain wrapping. The ball is forced through the line hydraulically. One plant uses such a device at least once every 8 hr to prevent plugging in lime-slurry piping.

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Mechanism of Corrosion

may explain problems

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The economic cost of corrosion in this country is tremendous. About ten years ago Dr. Uhlig, an authority on corrosion, estimated that the annual cost of corrosion in the United States was of an order of $5.5 billion. This included the actual loss of material by rusting, the money spent attempting to protect equipment from rusting and money spent on the other forms of corrosion protection, such as galvanizing.

Today, corrosion is a major concern as evidenced by the increased activity in the field of corrosion control. To discuss the phenomenon of corrosion, the definitions and terms used must be understood.

Review of Fundamentals

A knowledge of the fundamental concepts of chemistry is essential to an understanding of corrosion. First, concerning the composition of matter, it is defined as anything that occupies space and has mass. All matter is composed of molecules, and all molecules are composed of atoms.

A molecule is the smallest particle into which matter can be subdivided without destroying its characteristic properties. The atom, until recent times, has been thought to be solid and indivisible. The smallest part of a molecule, the atom, has been considered to be a unit of matter. Atoms of the same kind can combine with one another to form molecules of the same matter. Atoms of different kinds can combine to form molecules of a new kind of matter which may sometimes be referred to as compounds. We are frequently dealing with this latter type of reaction between different sorts of atoms. For example, iron may combine with oxygen to form iron oxide. Here one kind of atom, iron, combining with another kind of atom, oxygen, formed a new molecule, iron oxide.

Originally, it was assumed that the atom was the smallest particle into which matter could be divided. Later developments have indicated that this theory was incorrect and it is now assumed that the atom is actually made up of a number of distinct particles — principally charges of electricity. In the atom we normally have a *nucleus*, or center, made up of positive charges, and around this center we have revolving, very much as our earth revolves around the sun, negative electrical charges or *electrons*. Depending upon the particular kind of matter involved there may be a large number, or a small number of electrons revolving around the nucleus and they may be revolving in several orbits. When an atom loses or gains an electrical charge, it normally undergoes some type of chemical reaction. For example, when ordinary metallic iron loses an electrical charge or charges it becomes a kind of iron which we refer to as an *ion*. Matter in this condition can react readily with other types of matter and we say that the material is in the ionic condition. Normally, matter exists in the ionic condition only in the presence of water. There are exceptions to this statement. For our purposes one point should be emphasized: For most of the chemical reactions occurring in corrosion which concern us, the presence of water is an absolute essential; therefore, without water, there can be no ions and no corrosion.

Contributing Factors

In water systems the principal factors influencing corrosion of ferrous

Corrosion is an electrochemical reaction, and normally oxygen and moisture must be present for corrosion to be effective. Likewise, the elimination of oxygen or moisture from a metal surface automatically reduces its tendency to corrode.

metals are the water characteristics, temperature, rate of flow and the contact of dissimilar metals. The chief variables controlling the characteristics of the water are its dissolved oxygen content, carbon dioxide concentration, pH and dissolved solids. Other factors are involved, of course, such as the possible presence of free mineral acids, hydrogen sulphide and sulphites, carbon dioxide, etc. In addition, certain bacteria may be a factor. The presence of oxygen is usually essential for serious corosion to take place in natural water. Dissolved oxygen will greatly accelerate corrosion in acid, neutral or slightly alkaline water.

Corrosion of Iron

Corrosion of iron in water may be expressed in a simplified way by the following chemical equations:

$$(1)\ \ \frac{Fe}{\text{Iron}} \rightarrow \frac{Fe^{++}}{\text{Ferrous}} + \frac{2e}{\text{Electrons}}$$

$$(2)\ \ \frac{2HOH}{\text{Water}} \rightarrow \frac{2\,OH^-}{\text{Hydroxyl Ions}} + \frac{2\,H^+}{\text{Hydrogen Ions}}$$

$$(3)\ \ \frac{Fe(OH)_2}{\text{Ferrous Hydroxide}} + \frac{2\,H}{\text{Hydrogen Atoms}}$$

In these equations plus signs have been used for positive electrical charges or ions and minus signs for negative electric charges or electrons. In equation (1), it will be noted that iron in water dissolves and because water is present, the iron which has dissolved loses two electrical charges, becomes positive and is called ferrous iron. There are two free negative electrical charges floating around. In (2), the water to which the iron is exposed breaks down to form two OH^- groups which carry one negative electrical charge each, called hydroxyl ions. In addition, there are formed two hydrogen ions each of which carries one positive charge. The total number of positive and negative charges is equal. The ferrous ion with two positive charges reacts chemically with the hydroxyl groups which have one negative charge each. The two *pluses* cancel out the two minus charges and the result is (3), a new compound ferrous hydroxide, or rust, on the one hand and hydrogen gas on the other. In this case, rusting occurred without oxygen being present. But water was present, and is an essential in the majority of corrosion reactions.

For this kind of corrosion or chemical reaction to continue there must be some way to get rid of the hydrogen gas which is formed. Rust must be removed from the surface of the iron where it has been formed. If these things are not done then eventually the reaction will stop and we say that corrosion has been inhibited or stopped.

One of the things which is essential to corrosion is the removal of one of these materials from the field of action. Now, ferrous hydroxide is not very soluble in water. Hydrogen gas likewise is not very soluble. When the water has dissolved all of the ferrous hydroxide which it can, the excess will form as a precipitate. In the case of hydrogen gas the excess will pass out as bubbles. Frequently, however, the hydrogen cannot escape. This occurs when the hydrogen is formed as an extremely thin layer on the surface of the iron. This is extremely difficult to remove. Unless removal does occur, the hydrogen covers the surface of the iron very much as a film of paint might do, and effectively stops any further chemical reaction or corrosion. It is at this place that the need for oxygen comes into play. In addition to (1) (2) (3), two additional chemical reactions may occur. These are indicated below.

$$(4)\ \ \frac{2H}{\text{Hydrogen Atoms}} + \frac{\frac{1}{2}\,O_2}{\text{Dissolved Oxygen}} \rightarrow \frac{HOH}{\text{Water}}$$

$$\text{or } (5)\ \ \frac{2H}{\text{Hydrogen Atoms}} \rightarrow \frac{H_2}{\text{Hydrogen Gas}}$$

The atmosphere contains about 21% oxygen gas by volume. This is dissolved quite readily in water. It is in fact almost impossible to obtain water which is completely free of oxygen. The presence of oxygen in water makes it possible for it to support aquatic life but at the same time makes it a much more corrosive medium. The first reaction shows how oxygen can make the corrosion of iron continue where otherwise it might be stopped. For example, from the initial reactions we find that ferrous hydroxide and hydrogen atoms are formed. If these hydrogen atoms cover the the iron surface they protect it and no further corrosion will take place. On the other hand if oxygen is present it will react with hydrogen atoms to form water (4) and thereby remove them and permit the reaction to proceed. In natural waters, dissolved oxygen is the controlling factor and corrosion is almost directly proportional to the oxygen content of the water.

Corrosion can occur without the formation of hydrogen gas and can be continued by the reaction of oxygen with the hydrogen, as it is formed, to produce water.

If the hydrogen is removed by other means the same result will be obtained. For example, if hydrogen or some other gas could be bubbled against the iron surface it would make it much easier for the hydrogen to get away and the second reaction (5) would occur; that is, the hydrogen atoms would combine to form a molecule of hydrogen gas which would leave the solution.

Return now to equation (2), the equation which showed how water could be decomposed into hydroxyl ions and hydrogen ions. It is the hydrogen ions which eventually form the hydrogen gas in the reaction just discussed. Attention is drawn, however, to the hydroxyl ion since it, too, plays an important part in the corrosion reaction. pH is a measure of hydrogen ion content of a solution. If the pH value is 7 or greater the solution is alkaline and if it is less than 7, the solution is acidic. It is the alkaline feature which is to be discussed now. In these reactions, when the hydrogen atoms are pro-

duced, the iron reacts with the hydroxyl iron to form ferrous hyroxide. This compound is not very soluble and will oxidize and precipitate from solution as rust. This rust will cover the surface of the iron. It will act as a protective coating and may eventually stop the corrosion reaction. A film, whether it be of hydrogen gas or of ferrous hydroxide, provided it completely covers the surface, will protect that surface from corrosion just exactly as will a very good coat of paint or lacquer.

The iron forms not one but a number of different hydroxides. The one shown in reaction (3) is very light in color and relatively soluble. This type of compound will be seen formed in water which has been drawn from a well and allowed to stand in a filled bottle. If this compound is brought into contact with more oxygen it will be oxidized to a slightly different compound called ferric hydroxide which has a red color. This is the more insoluble compound and the one which normally appears on iron surfaces as rust.

Electrochemical Reaction

Corrosion is an electrochemical reaction. The features of an electrochemical reaction are best explained using a boyhood experiment in which a strip of copper and a strip of zinc are placed in a container of dilute hydrochloric acid. A wire attached to each piece of metal will produce an electric current. This operation is a galvanic cell. As a result of the chemical reaction electricity was produced. The combination of these metals caused an electrochemical reaction. In this particular reaction one of the metals, the zinc, is dissolved in the acid and hydrogen gas is liberated. The other metal is relatively unaffected by the reaction and continues in service for long periods of time using up several portions of zinc for the one portion of copper. In a cell of this type, the material which reacts or corrodes, is called the *anode*. The material which does not react chemically or dissolve is called the *cathode*. In corrosion reactions the metal which corrodes is referred to as the anode in the corrosion cell and some other portion of the system is called the cathode.

Ferrous metals exposed to a solution at low pH values will be corroded. Normally, the presence of dissolved oxygen or dissolved carbon dioxide accelerates corrosion particularly in solutions which are 7.0 pH or less.

Differential Aeration

The anode-cathode concept comes into play in the corrosion of iron by water and oxygen. In the electrochemical reaction, two different metals make up a galvanic cell. This is also referred to as two metal or dissimilar metal corrosion. However, it is not necessary to have two different metals for corrosion to occur. Actually, one metal in two different concentrations of oxygen will produce a corrosion cell. This is illustrated by corrosion which has caused pitting of an iron pipe or a piece of iron plate. This type of corrosion is frequently referred to as differential aeration corrosion. Logically, one would assume that if one portion of the metal was exposed to a high concentration of oxygen and another to a low concentration of oxygen that the portion exposed to the higher oxygen concentration would corrode slowly. Strangely the reverse is true. This phenomena can be illustrated for example by laying a piece of wood or other material over a spot on a sheet of metal. If the wood is allowed to remain in place for a sufficiently long period of time, under conditions of an abundant supply of moisture and oxygen it will be noted that the area under the wood has corroded or pitted and that rust has formed around the edges of the wooden block. The spot under the block of wood acts as the anode in this particular cell while the area around the edge of the block of wood acts as the cathode. It is the anode which always corrodes and the cathode which does not corrode but receives the corrosion products. In this case, the iron which dissolved and formed a pit under the wood, traveled, by virtue of the electric current generated, away from the anode and toward the cathode. When the iron continues to dissolve, the iron hydroxide being in contact with oxygen from the air is precipitated and forms a line or circular mound of rust around the covering bit of wood or other material. Differential aeration type corrosion is very common in water lines. If, for example, a small amount of soil, a piece of gravel, a bit of cloth, or any object is allowed to remain in an iron pipe, a tank, or on a metal surface it will usually exclude oxygen from contact with the surface immediately below it. If other conditions are favorable corrosion will occur below the object causing pitting. A similar situation occurs where iron or steel pipe is driven into water as a support for a dock or a similar type installation. In such cases it will usually be noted that the iron does not corrode at the water's edge but corrodes at a point a few inches below the surface of the water. This is another and very common illustration of corrosion caused by differential aeration. This is an electrochemical type reaction but all of the reaction occurs with a single metal.

Stress Corrosion

Corrosion because of differences existing on the surface of the same piece of metal can be illustrated further. Where steel pipes or steel plates are welded together and the weld is not subsequently stress relieved, it will frequently be noted that severe corrosion occurs at the weld. This is usually designated as stress corosion. The explanation for this type of corrosion is simply that during the welding operation the physical condition of the iron was changed without changing its chemical composition. The iron in the area of the weld is different physically from the iron, say, 8 inches away from the weld. In the majority of such cases the iron at the weld is the anode in an electrochemical cell and the balance of the pipe is the cathode. If this pipe (and weld) is exposed to moisture and oxygen, corrosion will occur usually at the weld. Frequently failure will occur because of the differences in the metal as a result of the welding operation. The operations known as normalizing, stress relieving, etc., are normally intended to overcome this difficulty.

Acidity — Alkalinity

The pH value of the water to which iron is exposed has a very powerful effect on the rate of corrosion. At pH values below 4.3 the controlling factor in corrosion is pH. The hydrogen

film formed is destroyed rapidly by the evolution of hydrogen as a gas. In this range, too, the metal ions entering the solution remain soluble and no insoluble reaction product results. In the absence of a barrier, or protective film the corrosion rate in acid solutions is, therefore, quite high. When the solution contains dissolved oxygen in addition to a pH value in the low range mentioned, the rate of corrosion is further accelerated.

At pH values above approximately 9.5, the alkalinity increases and the pH or hydrogen ion activity decreases. The reaction illustrated earlier between iron and hydrogen ions is retarded. In addition, the red coating formed in alkaline solutions is more protective than the one formed in neutral solutions, and the rate of corrosion is appreciably decreased. In fact, a hydrogen type corrosion will not take place at normal temperatures in the absence of dissolved oxygen. However, in the presence of dissolved oxygen, the rate at which hydrogen can be removed is the controlling factor. While the rate of corrosion will be appreciably decreased a serious amount can still result. At pH values between 4.5 and 9.5 the presence of dissolved oxygen plays a more important role than pH value.

Practically all natural water contains small amounts of dissolved carbon dioxide. This is present in the atmosphere to the extent of about 0.04% by volume. It is quite soluble in water at ordinary temperatures and in consequence will practically always be found in water to a greater or lesser degree. Carbon dioxide combines with the water to form carbonic acid. This is one of the constituents which makes carbonated beverages appeal to the palate. It also promotes the formation of hydrogen ions, and water containing carbon dioxide will usually be acidic, and in the pH range of 3.5 to 5.5. Even where dissolved oxygen is not present the carbon dioxide will make the water corrosive to iron. This effect is not too serious at ordinary temperatures but can be the source of considerable damage at elevated temperatures such as prevail in steam boilers. Here great care must be used in removing all traces of carbon dioxide and oxygen from the boiler feed water to prevent corrosion of the steam tubes and other parts of the equipment.

The chemical reactions which are shown below illustrate what happens when water containing carbon dioxide comes in contact with iron.

$$\underset{\text{Carbon Dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} \rightarrow \underset{\text{Carbonic Acid}}{H_2CO_3}$$

$$2\,H_2CO_3 \rightarrow \underset{\text{Hydrogen Ion}}{2H^+} + \underset{\text{Bicarbonate Ion}}{2HCO_3^-}$$

$$Fe \rightarrow \underset{\downarrow}{2e} + \underset{\downarrow}{Fe^{++}}$$

$$\underset{\text{Atomic Hydrogen}}{2H} + \underset{\text{Iron Bicarbonate}}{Fe(HCO_3)_2}$$

The carbon dioxide first reacts with the water to form carbonic acid which subsequently decomposes to produce hydrogen ion and bicarbonate ions as indicated. The iron meanwhile has produced two electrons and one ferrous ion. A reaction ensues and as a result we have atomic hydrogen coating the surface of the iron and the compound iron bicarbonate formed in solution. Since the iron bicarbonate is soluble it stays in solution and the corrosion proceeds as fast as the hydrogen is removed. The higher the pH of the solution the more difficult it is to remove the hydrogen as a gas and the slower will be the corrosion reaction. If any oxygen is present it will react with the ferrous bicarbonate to precipitate it. Normally, this material will be deposited on the surface of the metal and act to inhibit the rate of corrosion.

Protection

Aluminum and Chromium Coatings

Several times, it has been mentioned that the formation of any type of protective coating over the surface of the iron will reduce the rate of corrosion and may completely stop it. The best protection against corrosion is the formation of some type of film on the surface of the metal which will not be attacked by water or oxygen. The principal reason that aluminum has found such wide use is because of this peculiar ability it has. The same reason explains the extensive use of chrome trim on automobiles and many types of home furnishings. In the case of both aluminum and chromium the metals are very reactive and are attacked easily by oxygen in the air. The chromium oxide or the aluminum oxide which are formed are both colorless and transparent compounds. They also stick very tightly to the surface of the metal. As a result as soon as corrosion has started a film is formed which prevents oxygen and moisture from reaching the surface of the metal and therefore stops the corrosion. If this were not the case it would be impossible to use aluminum in cooking utensils and in many other common applications. The same explanation holds for the chrome trim on automobile parts.

The chromium oxide which is formed is a very effective protection of the surface against corrosion. Since films are so effective in stopping corrosion the question naturally arises, if the metal does not form its own film can we artificially produce a film for it.

Inhibiting Compounds

Inhibitors are materials which can be added to water, solutions, etc., to prevent corrosion of the metal. Unfortunately, for most purposes inhibitors are not too satisfactory because they are usually organic compounds of a toxic nature which would render water supplies impotable. A wide variety of materials can be utilized as inhibitors to prevent the attack of iron by acid or by acidic waters. One of those which has been suggested is cabbage juice. Glue is reasonably effective for the same purpose. Very high efficiency has been achieved in this field by the use of complex organic compounds which give extremely effective protection of metal surfaces against attack by strong acids such as hydrochloric. The practice of acidizing oil wells is possible because of an inhibitor which will prevent the acid from attacking the surface of the iron and yet not render it ineffective so far as the lime rock formation is concerned. These inhibitors function very much as do the films previously mentioned. The inhibitor spreads itself over the surface

Corrosion can be effectively stopped if the corrosion reaction results in the covering of the anode or cathode surface with a protective film.

as will a film of paint and prevents oxygen, water and other corrosive materials from reaching the metal surface. The film has a number of weaknesses, however.

A film to be effective must cover the surface completely if it is the surface which is being attacked, that is, the anode. If any portion of the surface is not covered then the attack will be concentrated at that point and we have pitting. If the surface in question is the cathode then protection does not have to be so complete to reduce the corrosion rate substantially. The use of chromate inhibitors in refrigeration systems and the addition of small amounts of potassium chromate to brine solutions are examples of inhibitors used to reduce the corrosivity of solutions on metal equipment.

Effect of Temperature

A discussion on corrosion mechanisms would not be complete without reference to the effect of temperature on its reactions. It is a rule of thumb in chemistry that an increase of 10°C or 18°F will double the rate at which a chemical reaction proceeds. This is another way of saying that chemical reactions slow down as the temperature drops and speed up as the temperature rises. Reactions which are not harmful at ordinary room temperature can be very serious at the temperature of boiling water.

A temperature effect which is unusual but quite easily explained is that of corrosion because of differences in temperature at two points on a metal surface. The hotter section will usually be anodic toward the section of the metal at a lower temperature which is the cathode. Thus, on a pipe or plate which is at two different temperatures, the part at the highest temperature will usually corrode while the cooler section will not. This statement assumes that both sections will be exposed to the same atmosphere using a solution of some type.

Velocity of Flowing Liquid

Corrosion increases as the velocity with which the liquid flows by a point increases. The increase in corrosion with increase in velocity of water in a line is usually explained as due to the increased amount of oxygen which is made available per unit time at the higher flow rates and the more rapid removal of hydrogen by the same mechanism. Generally, there is a very rapid increase in corrosion rate as flow rate increases from about 1 foot per second up to about 4 feet per second. At higher rates the increase in corrosion is not so pronounced.

Corrosion protection may be obtained through the use of sacrificial anodes. A metal above iron in the Electromotive Series connected electrically to the iron surface will be corroded or serve as an anode and thereby prevent the iron from being attacked.

Dissimilar Metals

Corrosion frequently occurs to a very serious extent when two dissimilar metals are brought into contact. This is frequently noted where the threads of a steel pipe rust out at the point of entrance to a bronze valve. This type of corrosion is usually known as galvanic or two metal corrosion. The various metals which are available have been listed according to their tendency to corrode or to dissolve. This listing is referred to as the Electromotive Series of Metals. The most reactive metals are those which are normally not suitable for construction purposes. Such metals as sodium and potassium are very high on the list on the Electromotive Series and for that reason cannot be used in contact with water. The metals at the bottom of the list are those which are relatively non-corrosive, such as, platinum and gold. Iron occupies a position about mid-way in the series. An interesting thing about this series is that any metal which is above another metal in the series will be anodic toward that metal. Iron, for example, is above copper in the Electromotive Series. If iron and copper are brought in contact with one another in the presence of water, the iron will be the anode and will dissolve. The copper will be the cathode and will be unaffected. Generally, in a system in which a corrosive material is being handled it is extremely important to know your metals and know which metals will be attacked and which will not be attacked. In such cases it is wise to avoid having a combination of different metals in the series in contact with one another. Sometimes this fact can be used to advantage. This is the case with galvanized iron.

Cathodic Protection

Galvanized iron is iron which has been coated with a layer of zinc. Zinc is a metal which is ahead of iron in the Electromotive Series. When the two metals are in contact the zinc corrodes and the iron does not.

This is an example of cathodic protection. The iron, since it is below zinc in the electromotive series, is the cathode in the electrochemical cell while the zinc is the anode, or material which corrodes. Since the corrosion product of zinc is a white or transparent material which forms a tight adherent film, it will be appreciated that the zinc makes an excellent protecting agent for the iron sheets.

Cathodic protection has found rather wide application in certain fields. For example, most hot water heaters are provided with a bar or rod, usually of zinc, which actually protects the iron interior of the heater from corrosion and the formation of rust colored water. In a similar fashion, elevated water tanks are sometimes protected by the installation of the zinc electrodes which are attacked or dissolved and in that way prevent the iron from rusting.

It is necessary to caution against the indiscriminate use of cathodic protection. In such cases the transfer of electricity or electrons between anode and cathode is usually in a straight line. The easiest object to protect cathodically would be a length of circular pipe which could be almost ideally protected by a rod of zinc extending down the center of the pipe and equidistant from the sides. Here, the distance that the electrons would have to travel to reach any point of the iron surface would be the same so that the protection would be uniform across the surface of the iron. If the object is irregular in shape and protection is not uniform, then there is always the serious danger that one part may be protected while another part may be seriously exposed and actually caused to corrode more than would otherwise be the case. Cathodic protection has been applied to the protection of buried pipe lines, tanks of various sorts and similar applications. Each case must be carefully studied to determine the proper location of the sacrificial anode to insure complete and satisfactory protection.

Colored Water — Red, Black or Blue

by JOHN J. HAMILTON and MARTIN E. FLENTJE,
respectively, Chemist and Chief Sanitary Engineer, American Water Works Service Co., Philadelphia, Pa.

Although the title of this paper may seem facetious, it should be understood that the authors do not consider at all funny the troubles associated with these types of waters. Red and black water are still the source of many consumer complaints, and the blue-greenish stains caused by waters aggressive to copper are far too common to be considered humorous. This paper reviews and discusses some experiences with such waters.

Causes and Corrections

By the term "red" water is generally meant the reddish-orange colored, somewhat turbid, clothes-staining water the consumers of public water systems get under certain conditions. Red water gets its nickname because it has suspended in it finely divided particles of iron rust in the oxidized, ferric state (Fe^{+++}). Such water generally has a total iron content of 2.0 ppm or over (some present as ferrous iron), it leaves an unsightly ring on the bath tub and stains on fixtures, and quite badly discolors clothes washed in it. Part of the staining of clothes is caused by the oxidation of the dissolved ferrous iron portion occurring through the use of a chlorine bleach solution.

Red water may be caused by sending an iron-bearing water to the distribution system without removing the iron, as may occur with an iron-bearing well water or with insufficient or incorrect treatment of a surface water containing acid mine wastes. As such waters absorb air, the iron is oxidized and the water becomes discolored.

More generally the cause of red water is the introduction of an aggressive, corrosive water into a system containing unlined cast-iron or steel pipe. Red water may also follow mechanical cleaning of iron or steel mains.

Red water generally can be controlled quite well by raising the pH of the water being treated to a value where it is close to or slightly over the calcium carbonate equilibrium point. Use of one of the polyphosphates is generally also successful; and because of the ease of application, many corrosive water sources are treated with these compounds. These chemicals may be used with and without pH correction down to a value of about 6.0. For pH correction, lime is the most economical and best alkali; soda ash and caustic soda can also be used. Liquid caustic soda [50 percent Na(OH)] is now quite generally available in drums and in tank truck lots, and in this form deserves more consideration in pH correction problems than it has received.

The foregoing statements could have been taken from a number of books and papers. But experience indicates that the solution to red water problems is not always as simple as such brief statements would lead one to believe.

Red Water Following Change in Water Character

In the authors' experience, they have run into several cases where red water conditions followed installation of an iron removal plant. In one case, where the iron-bearing water had been used for quite a long period, the red water condition lasted for a long time but finally cleared up. In a more recent experience, red water complaints were received from a system following introduction of iron removal, even though the raw well water had been

Ed. Note: This paper was presented at the Pennsylvania Water Works Operators Assn.; State College, Pa., and is published here by permission.

TABLE 1
Iron Pickup in System, 1956[1]

Location	Date	Alk., ppm	pH	Fe, ppm
Station Effl.	(Avg.)	150	8.1	0.05
Tap A[2]	9/2	130	7.2	1.00
	9/7	110	7.4	0.80
	9/13	152	7.6	0.80
	9/21	140	7.4	0.80
	9/29	146	7.3	0.45
	10/13	146	7.7	0.40
Tap B[3]	9/21	144	7.5	1.00
	9/29	140	7.3	2.00
	10/13	140	7.5	1.40

[1] Following installation of an iron removal plant.
[2] Approximately ¼ mi from station.
[3] Approximately ¾ mi from station.

TABLE 2
Turbidity and Lime in Filtered Water from Clear Well

Sample	Lime Added, ppm	Turbidity, ppm	pH
1	0	0	6.5
2	2.0	1.90	7.5
3	1.25	2.00	8.2+
4	1.25	5—10	8.2+

TABLE 3
Effect of pH on Iron Pickup in System, 1957

Location	Date	pH	Fe, ppm
Tap A	7/30	6.7	0.70
	8/5	7.9	0.30
Tap B	7/30	6.8	0.30
	8/5	8.1	0.10
Tap C	7/30	6.8	2.50
	8/5	7.9	0.50
Plant	7/30	7.1	0
	8/5	7.9	0

used (without iron removal) for only a few months. Table 1 shows analytical results from two distribution taps, the first approximately ¼ mile from the iron removal plant and the second ¾ mile away.

The pH values for these samples are generally above the staining curve of Baylis*; yet the water caused considerable trouble. This was attributed mainly to the low iron content water being in contact with old iron rust deposits. Part of the trouble was also caused by difficulty in obtaining uniform treatment with the equipment at hand. Dry feed of hydrated lime was first used, followed later by soda ash. A change to liquid caustic soda and the use of Calgon for about six months corrected this trouble.

pH and Red Water

The influence of pH on the prevention of red water is well understood and need not be gone into again here. The curves set up by Baylis are found to be a good guide for helping establish the pH to carry. In Alexandria, Va., for example, complaints concerning red water start whenever the pH of the water sent to the system falls below 7.6. These complaints came from the oldest section of the distribution system, where the cast-iron mains are not cement-lined and where some of the lines are 100 or more years old.

This plant has difficulty at times in getting sufficient lime into the treated filtered water to arrive at the desired pH without adding enough turbidity to make it objectionable. When this occurs, adding sufficient hydrated lime to get a pH of 8.0 causes the water to have a distinctly whitish, cloudy appearance—a water that could well be called "white" water. This is not due to the precipitation of free alum, but seems to be caused by slow solution of the lime or settling out of lime particles before going into solution. Table 2 illustrates what happens.

* Cox, Charles R., "Water Purification for the Practical Man." P. 70.

Both soda ash and caustic soda have been used while this lime problem is being investigated. In this period an opportunity existed to determine the effect of pH on the amount of iron pickup (Table 3) in the section of the Alexandria system previously mentioned.

Control with Polyphosphates

The use of polyphosphates for red water control has grown tremendously, and for good reason. These chemicals are easily applied and are effective at lower pH values than control with pH correction alone. This has been found to be of value in many cases, particularly in well supplies where the stations are automatically operated without attendants.

Water from the Raritan stratum in southern New Jersey quite often has a high carbon dioxide content and a corresponding low pH. In such supplies the polyphosphate feeding devices can easily be made to start and stop with the pumps, thereby reducing servicing of the station to one visit a day. Some of the Raritan stratum wells have pH values as low as 5.0, and in such locations liquid caustic soda plus phosphate treatment can be used.

In one plant such treatment has proven very effective. The pH is raised from approximately 5.3 to around 6.0 with liquid caustic soda to prevent copper solution, then sufficient Calgon is used to prevent red water. At this particular plant 4 ppm of Calgon is used, but some of this is used to sequester manganese—normally a dose of 1 to 2 ppm would be sufficient to prevent red water. Tables 4 and 5 illustrate how this treatment, which results in very little pickup of iron in the distribution system, works out.

Effects of Heavy Flushing

Many red water troubles are aggravated by excessive flushing. The usual procedure when a consumer complaint of red water is received at the water company office, is to send someone out to the affected area to flush out the offending water. This pacifies the customer who made the complaint because she sees activity resulting from her call; and usually, for the time being, this procedure clears up the water in that immediate area. However, this heavy flushing, done with the idea of tearing loose the deposits on the main often defeats its own purpose and prolongs and even aggravates the trouble.

This is true because for corrosion to proceed the water must come into contact with metal. The first step in corrosion is solution of iron from the metal surface. If oxygen is present in the water (and it is in practically every supply) this is followed by an oxidation step, which changes the iron in solution to insoluble ferric compounds. These tend to adhere to the metal and partially seal off the surface; unfortunately, however, in most cases this healing deposit is soft and only loosely adherent. Heavy flushing sets up velocities that tend to tear off this fragile loose deposit, and with its disappearance corrosive attack on the metal begins all over again.

In one system in western Pennsylvania, a 4-inch unlined cast-iron main 800 feet long was cleaned with a mechanical scraper to improve pressures and fire flows. The water supplied to this section came from an impounded reservoir source having a pH of 6.7 alkalinity of 12 to 16 ppm, total hardness of 26 ppm, and total solids of 85 ppm. Most of the remainder of this system consisted of cement pipe.

TABLE 4
Analysis of Well Water

Turbidity, ppm	0.40
Alkalinity, ppm	28
Total hardness	41
pH	5.3
Free CO_2, ppm	78
Iron (Fe), ppm	0.20—0.30

TABLE 5
Iron Pickup, Well Water Treated with NaOH and Calgon

Location	pH	CO_2, ppm	Alk., ppm	Fe, ppm	Increase in Fe, ppm
Plant	6.6	76	98	0.20	.....
A	6.4	88	90	0.20	0
B	6.3	98	78	0.18	—0.02
C	6.3	80	46	0.15	—0.05
D	6.3	90	40	0.10	—0.10
E	6.4	88	72	0.30	+0.10
F	6.4	98	70	0.15	—0.05
G	6.7	70	90	0.30	+0.10

TABLE 6
Analysis of Black Water, in PPM

Plant Location	C	Fe and Al Oxides	Al	Mn	SiO_2	Fe
Indiana	---[1]	302	132	1.00	---[1]	36
Connecticut	24	126	54	30	34	16

[1] Analyst's note: "Sludge of this sample is a mixture of free carbon, silica and hydroxides of iron and aluminum."

A soft water such as this would be expected to be quite corrosive.

Immediately after the cleaning operation, rusty water complaints began coming in in numbers from angry consumers. In attempting to clear up this condition, the cleaned line was repeatedly flushed hard, but this did not help. The situation became so bad that the water company, in desperation, was prepared to spend approximately $5,000 on a replacement line of cement-asbestos pipe. Fortunately, before this replacement work was begun, a suggestion was made that the method of flushing be changed to a procedure whereby the flushing hydrant was opened just enough and only long enough to gently change the water in the cleaned line. This was done early each morning to displace the water that had stood overnight in the line, and after about 10 days red water complaints ceased. The gentle flushing allowed the line to heal and become coated.

Conclusions on Red Water

Generalizing, experience with numerous red water difficulties leads to these conclusions:

1. The first step in investigating red water difficulties is to determine if the iron comes from the source or is picked up as the water passes through the distribution system.
2. Iron above 0.30 to 0.50 ppm in the source requires removal or sequestration.
3. In red water caused by corrosion within the system, bring the pH above the Baylis staining curve or slightly above the calcium carbonate saturation point; or
4. Use polyphosphate treatment with or without pH correction, depending on the pH of the raw water.
5. Be watchful for appearance of red water when a change in source of supply is made.
6. In flushing to clear out rusty water in an area from which complaints are being received, open hydrants only enough to gently change the water in the line. Let flow until water is clear and repeat rather frequently.
7. To prevent staining of clothes, advise consumers in effected area not to use chlorine bleach solutions, and suggest sending stained clothes to a commercial laundry for removal of stains. If home removal of stains is required, use ½ ounce of oxalic acid in 1 gallon of water, allow clothes to soak for 15 minutes, and rinse thoroughly in cold water.
8. Use cement-lined mains (where cast-iron or steel mains are desired).

Black Water

In recent years, there often have been "black" water complaints. These complaints were often from only one house in an area (usually the mayor's or a councilman's home, of course) and not always from the same house when the condition occurred again. The blackness is usually in the form of small, floc-like particles, light, somewhat greasy looking, and some of the material is finely enough divided to make the water brownish in appearance—or to appear stained brown. Clothes washed in such water come out with dark brownish to black stains or discoloration (which is aggravated by chlorine bleach solutions).

At first it was suspected that this condition was caused by carbon particles passing through filters, but closer examination has practically never shown much carbon in the distribution system. The real culprit is usually manganese, and it is apparent that this element is much more common and much more troublesome than suspected. Manganese may enter water supplies through acid mine wastes, through solution of manganese-bearing minerals (in wells), and through similar solution and organic decomposition in the bottom of reservoirs. Present in the manganous form, it is usually removed by oxidizing it to the manganic state; but this is much more difficult to accomplish than with iron. Oxidation of manganese is a very slow reaction at low pH values and the rate increases as the pH is raised. Any water with a manganese content of more than 0.05 to 0.10 ppm going into a system for several weeks will cause trouble with black water, and finally in deposits that increase friction losses.

TABLE 7
Showing Water Usage During Time of Black Water

Week Ending	Average Day, mg	Maximum Day, mg
July 6	12.38	14.11
July 13	14.01	15.90
July 20	13.70	15.92[1]
July 27	16.07	17.75[1]
August 3	12.47	13.90

[1] Complaints received.

Black water also has been found to be due to two other conditions: (a) any condition that allows free alum to pass into the system, and (b) a combination of free alum and silica from sodium silicofluoride.

In early 1956 at Davenport, Iowa, repairs being made on settling basins made it necessary to coagulate and settle the water being processed in roughly one-half the normal time. Low temperatures and exceedingly clear water at the same time made coagulation very difficult, and for several weeks free alum concentrations of between 0.50 and over 2.0 ppm (as Al—roughly equal to 6 and 25 ppm of filter alum) were present in the filter plant effluent. Hundreds of complaints were received on certain days when higher than normal water demands were made on the system. This water contained floc particles very much discolored with debris from the mains. Activated silica and extremely high optimum alum dosages, which resulted in lowered free alum, corrected this trouble.

At an Indiana plant a similar experience was found to be caused by free alum, silica, and some carbon. The appearance of the water samples in affected areas was very misleading because the suspended matter was black and looked very much like carbon. The analysis of this deposit is given in Table 6.

It was reasoned that the free alum was probably not sufficiently high to cause this trouble, but that the finely divided silica present in excess in the sodium silicofluoride added to the clear well provided a nucleus for the floc to form upon, and the floc then picked up material from the pipelines through which it passed. Good success was obtained in remedying this by changing the treatment to eliminate free alum and then changing the application point of the sodium silicofluoride to a point ahead of the filters.

In a fair number of plants black water has been caused by manganese. Manganese-caused black water is characterized by isolated occurrences

of the trouble; that is, several houses today of the 20 on a street, then others on the same street tomorrow. The disturbances occur when velocities of flow are above normal, as when peak loads are being met, when hydrants are flushed, or when the fire department decides it is time to practice fire fighting. Street flushing crews that open and close hydrants too quickly can also be the cause of such trouble. The only good solution of the problem of manganese-caused black water is almost complete elimination of the manganese at the treatment plant. One system has trouble if the manganese gets above about 0.05 ppm, probably because this system's transmission lines are very long (13 miles) and are all new, and are of concrete or of cement-lined metal or of cement-asbestos material. This tends to raise the pH and provide time for oxidation of any manganese that slips by the plant.

Another New England company struggled with a black water epidemic when the summer load appeared and the distribution system endured considerably higher than normal flow velocities and even reversals of flow, as shown in Table 7.

Blue Water

The term "blue" water refers to the blue stains caused by copper-bearing waters rather than to the color of the water itself. Possibly this use can be excused, because again it is desired to point out that copper corrosion is probably more prevalent than supposed.

In the southern New Jersey well supplies mentioned earlier, many cause copper stains in wash basins and bathtubs. These stains are usually found around the outlet drain; it is suspected that they are caused by the precipitation of copper compounds by alkali extracted from the porcelain.

TABLE 8
Copper Content of Tap Water from Several N. J. Supplies

Supply	pH (1)	pH (2)	Alk., ppm (1)	Alk., ppm (2)	Cu, ppm (1)	Cu, ppm (2)	Stains
A	6.4	6.7	22	22	0.4	0.5	No
A	6.7	6.8	23	17	1.5	0.2	Yes
B	8.4	8.4	77	79	0.08	0.05	No
C	7.3	7.3	53	51	tr	tr	No
D	6.3	6.3	45	41	0.9	0.4	Yes
E	6.3	6.3	16	12	2.0	0.95	Yes
F	6.2	6.1	22	16	2.5	0.2	Yes
G	6.0	6.2	45	42	0.5	0.3	?

Because the authors' company has been faced with several problems of treatment of such waters to eliminate these staining tendencies, which involve application of chemicals and economy in unattended automatic stations, it was necessary to know the pH needed to prevent excessive copper pick up. In the course of this investigation it was somewhat amazing to find the high content of copper that exists at times in household piping and causes no harm (see Table 8).

Tentatively, investigations show that a water with a pH of 7.0 or over will not cause staining of bathroom fixtures. It was thought that polyphosphates will not protect copper as they will iron, but there is some indication of help through the use of these compounds. Calgon alone will not prevent excessive copper pickup at a pH of 5.0 to 5.3.

One interesting case of copper corrosion trouble in the area served by supply F (Table 8) occurred in one side of a double house. The copper content of the water in this side of the premises has been so high so consistently that when vegetables are to be cooked water from the adjoining household must be obtained. This trouble began when all of the household piping was converted to copper pipe—the other side of the house still has a galvanized service line. Removing the power line and telephone grounds, installing a new service and an insulating coupling have not corrected this trouble.

In conclusion these suggestions (in addition to those made about the prevention of red water) are offered:

1. On black water control:
   (a) Reduce manganese to at least 0.10 ppm, and to almost 0 if possible;
   (b) Control the coagulation process so that free aluminum will be less than 0.30 ppm Al in the filter plant effluent; and
   (c) If sodium silicofluoride is being used, consider applying this chemical to the raw or settled water, ahead of the filters.
2. On blue water control:
   (a) Raise the pH to 7.0 or higher.

Automatic Analysis

for Silica and Hardness

by GEORGE SCHNEIDER

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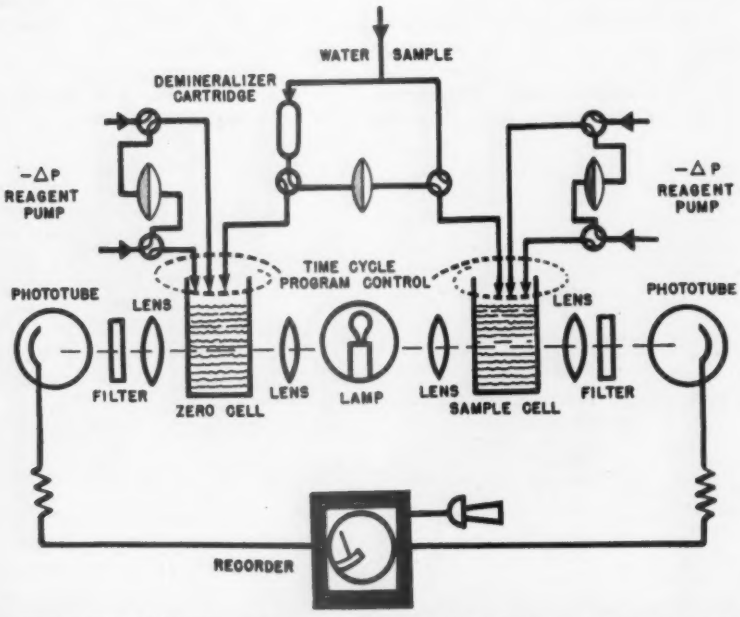
Design changes in power plants in recent years to use higher steam generating temperatures and pressures have necessitated changes in boiler water treatment. The newer plants require higher quality water with an absolute minimum of dissolved scale-producing compounds, including silica.

Fortunately, the development of demineralizers and water softeners has kept pace with the need for better water treating facilities, and it is possible to provide modern boilers with water of the necessary high purity. Also, up to a point it is possible to treat the water automatically.

Until recently, however, there has been no primary method for continuously measuring water hardness or silica content so that demineralizers can automatically regenerate in accordance with silica breakthrough. A typical "automatic" demineralizer had a conductivity recorder that detected any increase in dissolved solids at the middle of a bed and then rang an alarm or flashed a light. At the signal, it was up to the operator to run laboratory analyses for silica and regenerate the demineralizer when silica started to break through.

This method, of course, assumed that conductivity broke in the middle of the bed before silica broke through the bottom of the bed. Not only did the silica analyses require the time and attention of an operator, but the analysis techniques were complicated and employed rather delicate laboratory apparatus. The apparatus was expensive and did not meet specifications for ruggedness and durability as other equipment with which operators are familiar.



AUTOMATIC ANALYSIS and control of silica and hardness content by a colorimetric analyzer is accomplished by utilizing this scheme of operation.

Miniature Laboratories

To meet this need for a rugged, accurate instrument which would continuously measure silica content and automatically initiate regeneration of a demineralizer or softener, the author's department spent three years in developing and field testing a "Quantichem" colorimetric analyzer. These instruments are now installed in industrial power plants, where they are measuring and recording total hard-

ness of softener effluents or silica concentrations of demineralizer effluents.

Basically, these analyzers are miniature laboratories that automatically perform all steps of an analysis from flushing the sample cells to recording the results. The hardness analyzer makes a complete analysis every six minutes and the silica analyzer operates on a 12-minute cycle.

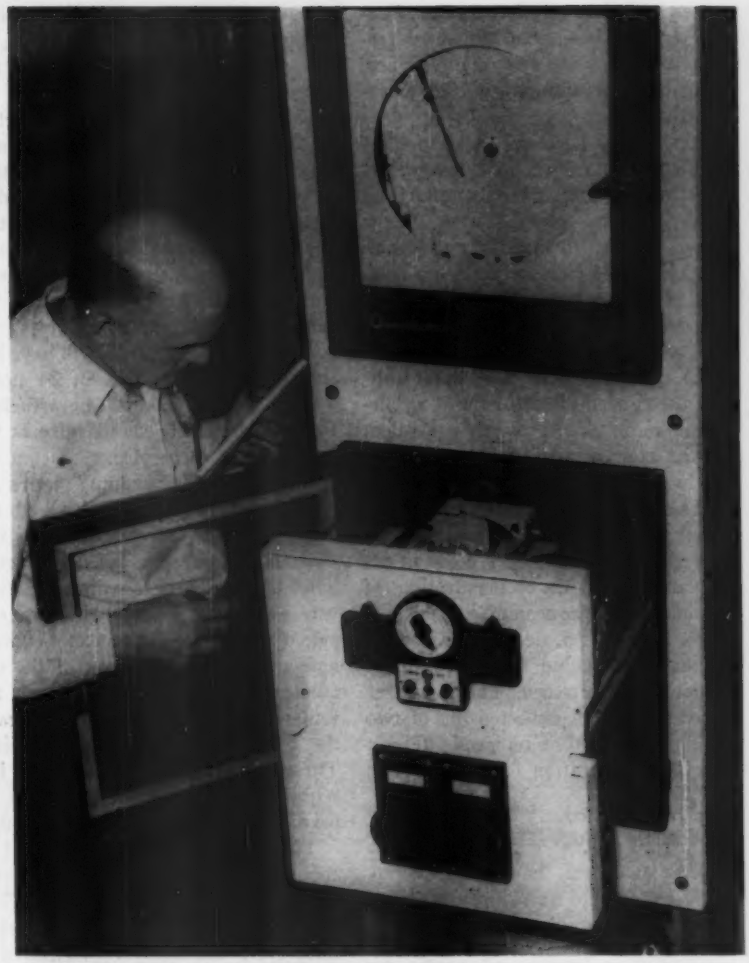
In a typical analysis the sample cells are flushed and drained. Then they are filled with metered samples of demineralizer or softener effluent and the instrument automatically standardizes itself. Then chemical reagents are metered to the cells and the difference in light transmittance between the zero cell and the sample cell is measured by photoelectric tubes in a modified Wheatstone bridge circuit. The resulting signal is recorded on a chart calibrated in terms of concentration. Finally, the cells are drained and the cycle is repeated.

Application of Beer-Lambert Law

The "Quantichem" instruments are colorimetric analyzers based on an application of the Beer-Lambert law. Simply stated, this law of physical chemistry says that if light of a given intensity and wavelength shines through two samples of colored solutions for equal distances, the difference in the intensities of light emerging from the solutions will be proportional to the difference in the concentrations of the coloring agent in the solutions.

To apply this law, the Quantichem analyzers prepare two solutions. One solution, in the zero cell, develops a color equivalent to a dye solution with no hardness-producing ions or silica. This is accomplished by passing the zero sample through a small demineralizer. The zero sample then has no hardness or silica content that can react with the reagents that are metered in like amounts to both samples. Then, according to the Beer-Lambert law, the measurement of the difference in light intensities emerging from the two cells is equivalent to the concentration of the specific ion creating the color in the sample cell.

In theory this colorimetric technique can be used to analyze continuously for any substance, but problems arise in putting theory into practice. First, it is necessary to determine chemical reactions in which the specific substance to be measured will cause a sufficient change without other substances interfering or clouding the solutions. Then, when the color changes that will occur in the analysis for a specific substance are known, it is necessary to determine the wavelength of light that will give the best accuracy for the range of concentrations to be measured.



CONTINUOUS automatic hardness analyzer installed in the power plant of a midwest oil refinery for constant check on the boiler makeup water with range of 0 to 3 mg/L.

The light source in the analyzer is a high-intensity light bulb. Optical filters between the light source and the photoelectric tubes screen out light of all wavelengths except that most affected by the color change. Because the same light source is used for the zero cell and the sample cell, no errors are introduced into the measuring circuit due to different aging characteristics of two separate light sources. In addition, the glass windows of the cells are shuttered to prevent errors from lights outside the instrument.

Silica Analysis

The silica analysis is based on a method developed by the Armour Research Foundation.* Four specific reagents are metered to the two samples in the cells. They are accurately metered by controlled-volume pumps through motor-controlled four-way valves operating on a programmed cycle to allow sufficient time for reactions to take place.

The first reagent is a buffer solution that maintains the pH at the optimum for the reaction to follow. The second reagent is ammonium molybdate, which reacts with silica and phosphorus to form hetero-polymolybdic acids. The third reagent added to each sample cell attacks the phospho-molybdic acid and decom-

* Robison, H. E., Pirsh, E. A., and Grimm, E., "The Spectophotometric Determination of Small Amounts of Soluble Silica in Water." Amer. Soc. Mech. Eng., Paper No. 51-A-92.

poses it. It has no effect on the silico-molybdic. Thus, after the third reagent is added the only complex acid remaining in solution is the silico-molybdic acid.

The fourth chemical to be metered to the sample cells is a reducing agent that reacts with the silico-molybdic acid to form colloidal molybdenum blue. Excess chemicals are metered to the sample cells so that this reaction always goes to completion. It is the concentration of molybdenum blue that determines the intensity of the light emerging from the sample cell; but the concentration of the molybdenum blue in turn is exactly equivalent to the concentration of the silica in the water tested.

The hardness analyzer uses but one reagent, which contains the dye and buffer. The dye changes color in accordance with the concentration of calcium and magnesium ions in the water. Again, a de-ionizer is used so that there is no calcium or magnesium in the zero cell. The de-ionizer cartridge has an expected life of two years, but should be replaced after six months of operation for best results.

Analyzers Employ Wheatstone Bridge Circuit

The analyzers have Wheatstone bridge circuits to transduce the difference in light intensity to a movement of the recording pen. The two phototubes are variable resistances in the bridge. Small direct-current signals resulting from an unbalance in the bridge circuit, when the intensities of light reaching the phototubes differ, flow through a chopper that converts them to alternating-current signals. All the a-c signals are amplified and become correction signals for the balancing motor which moves a slidewire positioner in the correction direction to rebalance the bridge circuit. Simultaneously, it moves the recording pen to a new position indicative of the results of the analysis. The slidewire potentiometer is of the single-turn precision type with a linearity of ± 0.1 per cent.

Program Controller Uses Commutator Plate

The entire program for an analysis is established through a commutator plate. A timer sweeps an arm of small wipers around the plate to make the necessary electrical circuits. A dial on the front of the analyzer shows the progress of the program, which can be changed manually if desired. Also, the operator can stop the program at any stage to check the equipment.

During the standardizing portion of the program, if there is too much dirt on the cells and the Wheatstone bridge circuit cannot be balanced, a small light signals the operator that the cells must be cleaned. A second light on the analyzer signals the operator whenever the light source is too dim and must be replaced. Tests have shown that the analyzers will have less than 10 per cent drift in 24 hours without standardization; nevertheless, they automatically standardize at the beginning of each cycle.

Small controlled-volume pumps are used to meter the samples and the reagents. These pumps have two chambers separated by diaphragms. Through the programming of four-way valves a reagent flowing into one side of a pump forces an exact equivalent amount of liquid out of the opposite side of the pump. When the four-way valves are switched again, the flow is in the opposite direction. These pumps are highly accurate, but require a suction pressure at least 10 psi higher than the discharge pressure.

The sample supply is controlled at about 10 psi pressure by a back-pressure valve which permits a small flow to drain continuously. Thus, during each cycle the analyzer measures a fresh sample and not one that has been dead-ended in the piping.

To provide the necessary pressure on the reagents, the analyzers use small accumulator-type pumps that mount directly on the reagent bottles. These pumps operate on 15- to 20-psi air supplies and are regulated through a three-way solenoid valve controlled by the programmer.

Extra Features For Industrial Applications

In developing the analyzers, the designers were aware of the requirements of American industry for rugged equipment giving long service life with minimum maintenance.

The analyzers are built in two units —one housing the analysis equipment and the other housing the recording and controlling circuits. Preferably, these two units are mounted together; but they may be separated by as much as 50 feet.

Unitized construction with easy plug-in assemblies permit quick replacement when necessary. The glass windows of the cells are easily removed so that the cells can be cleaned without disturbing other parts of the instrument. To preven electrostatic or instrument. To prevent electrostatic or system, all external electrical wiring and components are fully shielded.

Analyzers in the Control Circuit

These instruments are designed to improve the control of water treatment facilities, whether the need be for alarms or for an automatic control system. The recording units are equipped wth high-low limit switches that can be used to actuate alarms, such as horns, bells, or lights. With the switches being adjustable over the entire range of the instrument they are also usable to start programmers for regeneration of a demineralizer or softener.

In a typical, completely automatic control system for a demineralizer, the high alarm switch is set for a silica concentration of 0.02 mg/L; whenever the silica content in the boiler make-up water exceeds that amount, the switch closes an electrical circuit that starts an external program timer. The timer, in turn, accuates solenoid valves and lights which control and indicate the position of pneumatically-operated valves.

With the valves opened and closed automatically in sequence, the demineralizer can be regenerated and returned to stream without the operator having to touch a button. His primary duty will be supervisory and he will be expected to step in and take over if unforeseen difficulties should ever develop. The automatic analyzer is the link that closes the control loop and makes completely automatic water treatment possible.

Instrument Ranges

The colorimetric analyzers described are manufactured with two standard ranges—0 to 3 and 0 to 5 mg/L calculated as calcium carbonate. These instruments have sensitivities of 0.3 and 0.05 mg/L, respectively.

The silica analyzers have standard ranges of 0 to 0.5 and 0 to 0.05 mg/L calculated as SiO_2. The higher range instrument is accurate to within ± 1 per cent, while the instruments with the latter range have an accuracy of ± 5 per cent. These are the ranges found to be most useful for controlling boiler water treating facilities.

Dissolved Oxygen Determination

by ISADORE NUSBAUM

Senior Water Pollution Control Engineer, Calif. Water Pollution Control #9, San Diego, Calif.

The use of sulfamic acid as a replacement for sodium azide in the modified Winkler method for dissolved oxygen in samples containing nitrites was recommended by Cohen and Ruchoft.[1] It was also shown that sulfamic acid could be effectively used to preserve biologically active samples for a delayed dissolved oxygen determination. The procedure recommended had no specific advantage over the azide modification of the Winkler method[2] and actually required the preparation of a special reagent and an extra step in the analysis.

The transport and use of sulfuric acid in the dissolved oxygen method particularly in field work has been a source of aggravation and has resulted in damage to equipment, clothes and person in a great many instances. Even in the laboratory the use of concentrated sulfuric acid in the Winkler determination has made more than usual caution necessary. Hydrochloric and ortho phosphoric acids have been substituted for sulfuric acid but increased volumes are required. These acids are not without problems as well.

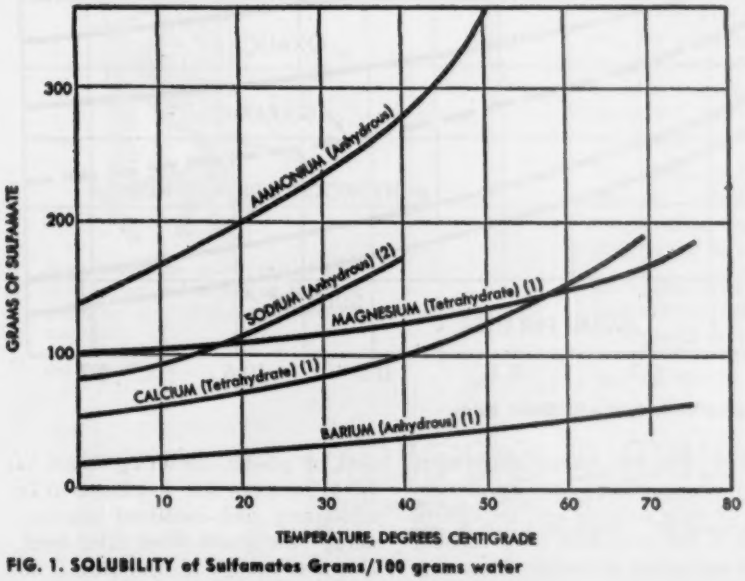


FIG. 1. SOLUBILITY of Sulfamates Grams/100 grams water

Availability of Acid

Sulfamic Acid (NH_2SO_3H) is a readily available, inexpensive, relatively non-hazardous white crystalline solid acid.[3] It is non-volatile and non-hygroscopic. Sulfamic acid has been shown to be close in strength to sulfuric, hydrochloric and nitric acids yet it is much less corrosive. The calcium, barium and magnesium salts of sulfamic acid are quite soluble. Figgures 1, 2 and 3 show the solubility of the acid in water, its comparative strength and the solubility of some of the salts.

One of the important industrial uses of sulfamic acid is based on the ability to remove nitrites and nitrous acid from solution.

$$HOSO_2NH_2 + HNO_2 \rightarrow H_2SO_4 + H_2O + N_2\uparrow$$

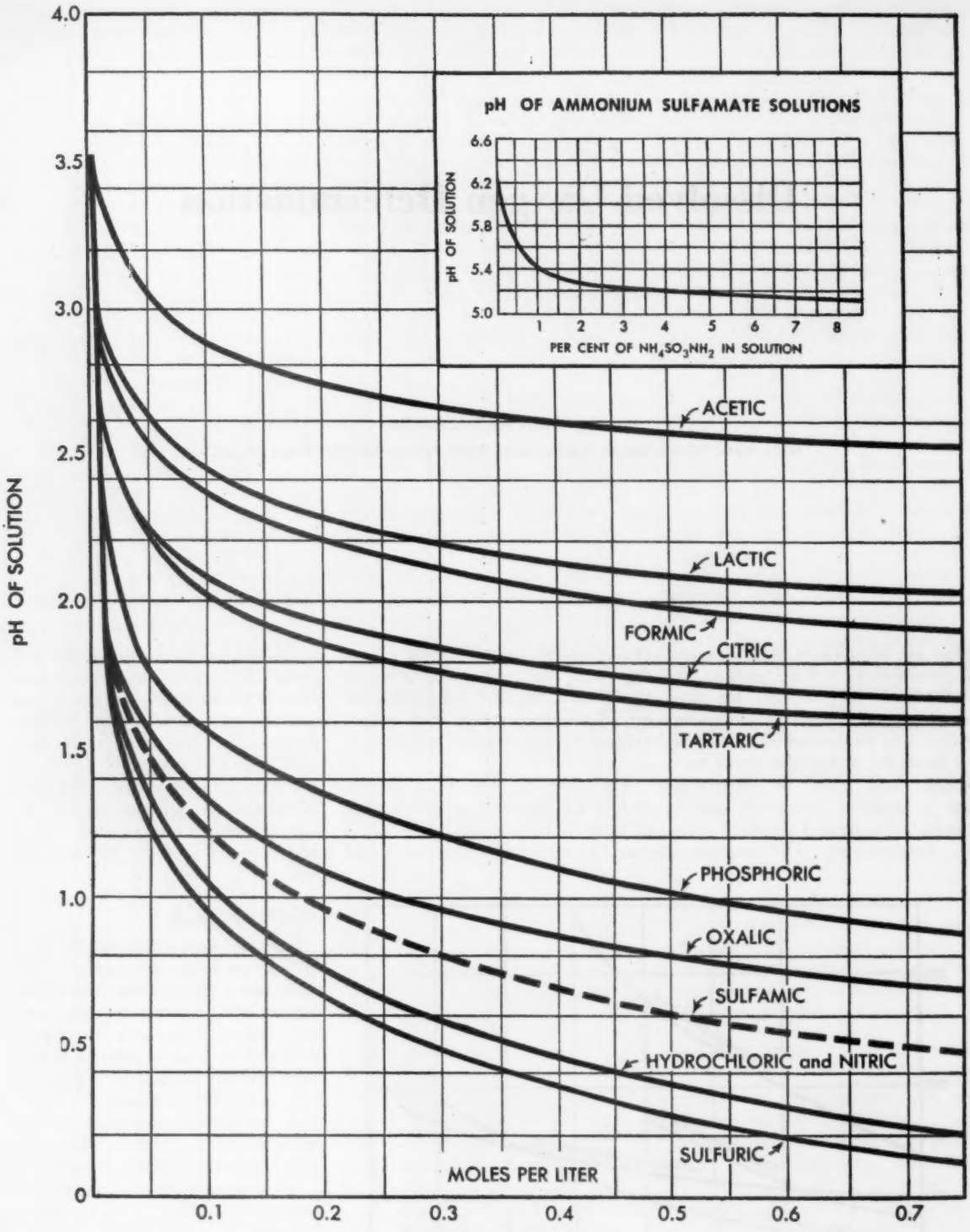


FIG. 2. pH CONCENTRATION Curves Comparing Sulfamic Acid with Other Acids

Sulfamic Acid is reported as two to six times more effective than urea for this purpose and about two-thirds as effective as sodium azide in the modified Winkler method.[1]

The dissolved oxygen determination was modified first by directly substituting sulfamic acid for sulfuric acid in the procedure. The sulfamic acid was added as a solid. A stainless steel or plastic measuring spoon of the ½ teaspoon size was found to be satisfactory and contained approximately four grams when filled level. This was enough to neutralize 2 ml

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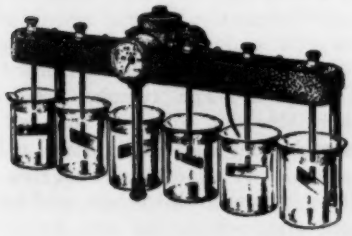
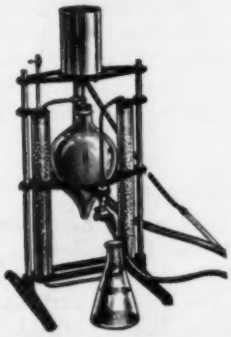


When several samples are mixed simultaneously under identical conditions the optimum concentration of flocculent may be quickly selected and translated to plant quantities. . . . The mixer takes 1,000 ml. beakers. Speeds from 10 to 100 r.p.m. are standard.

Cat. No. 77-700

ENSLOW

Stability Indicator



For checking the equilibrium of a finished water, and supplying an index useful in controlling anti-corrosion treatment.

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The effluent sampler is the answer to the problem of taking samples periodically from effluent streams, rivers, etc., for compositing and analysis. Mechanical sampling in this manner is more dependable, because the time cycle is more precise, and the volume of each sample is accurately controlled. The only time required of personnel is that involved in changing receivers.

This Effluent Sampler is compact, portable, simple to operate, with a self-priming pump that lifts liquid to a height of six feet, and an easily-regulated by-pass feeder. Practically no maintenance is required.

Full operating instructions are furnished with each instrument. Additional electrical outlets are provided, along with ample storage space for cord or extra tools.

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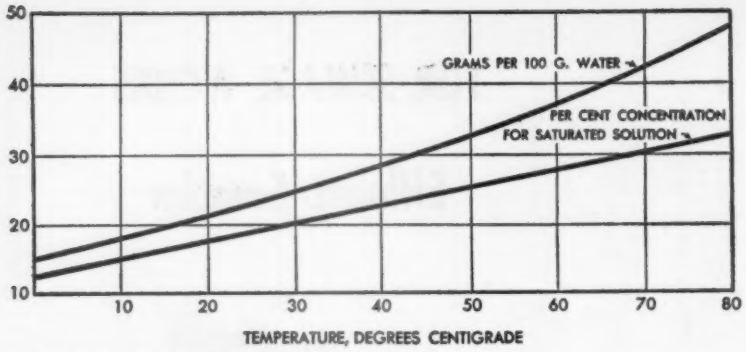

FIG. 3. SOLUBILITY of Sulfamic Acid in Water.

of the alkaline-iodide reagent and acidify the sample. A small amount of the crystalline acid will remain within the cupped area of the conventional B.O.D. bottle. It is not necessary to force all of this material into the bottle. The ground glass stopper may be replaced and the sample shaken.

The possibility of an error due to interstitial air in the solid acid was investigated and no significant difference between samples acidified with either sulfuric or sulfamic acid was found. Some comparative analyses are:

Dissolved Oxygen (mg/L)

Sample	Acidified with: H_2SO_4	NH_2SO_3H
BOD water	8.0	8.0
Tap water	9.2	9.2
BOD water	8.15	8.1
Prim. eff.	0.1	0.1
Prim. eff. & BOD water	5.0	5.0
BOD water	8.1	8.1
BOD water	7.9	7.9

Nitrite Interference Absent

The possibility that the sulfamic acid would destroy nitrites under the circumstances described above and thus eliminate the nitrite interference to the D.O. determination was then investigated. The nitrite interference does not occur in the dissolved oxygen method until the final acidification. The nitrites in acid solution then react with potassium iodide to produce iodine as in the following equation:

$$2I^- + 2NO_2^- + 4H^+ \rightarrow 2H_2O + 2NO + I_2$$

The reaction of sulfamic acid with nitrite appears to be slower normally than the reaction of nitrite and iodide ions in acid solution. When a solution of sodium nitrite and potassium iodide in distilled water is acidified with sulfamic acid, copius amounts of free iodine are released. However, in the dissolved oxygen determination a different condition exists. The sample is strongly alkaline before acidification and, therefore, the change in pH is more gradual upon the addition of the sulfamic acid. The reaction between nitrite and iodide requires a pH of about 3. The sulfamic acid, therefore, has an opportunity to react with the nitrite ion and destroy it before the nitrite-iodide reaction takes place. Several of the determinations in Table 1 were run with an additional sample containing several parts per million of nitrite ion. No significant nitrite error was found when sulfamic acid was used to acidify the sample, as shown by these data.

Apparent Dissolved Oxygen (mg/L)

Sample	Nitrite Added		No Nitrite
Acidified with:	H_2SO_4	NH_2SO_3H	NH_2SO_3H
BOD water	9.6	7.9	7.9
Prim. Eff.	8.8	0.4	0.4
BOD water	10.3	8.1	8.1

The solutions and procedure suggested for setting up a sample for the determination of dissolved oxygen, particularly in field work, would follow the unmodified Winkler method[2] with regard to the manganous sulfate solution and the alkaline-iodide reagent. Instead of the concentrated sulfuric acid, ½ level teaspoon or 4 grams of sulfamic acid are added to a 250 to 300 ml sample. The sample is vigorously shaken and titrated as normally. It is not necessary to add sodium azide to the alkaline-iodide reagent.

Field Kit

In setting up a field kit for dissolved oxygen analyses, several ideas have been tried and successfully used which might be of value to others. The writer has used a solid soluble starch available almost everywhere instead of the conventional starch indicator solution. The material is known as Niagara Soluble Starch and is soluble in cold water, stable and quite inexpensive. A small amount of the solid is added to the sample being titrated before the endpoint is reached. The starch-iodine complex has a slight blue-pink color near the endpoint but the endpoint is sharp and easy to see. An inexpensive but effective substitute bottle has been used for both dissolved oxygen and B.O.D. analyses. A conventional 24 or 28 mm screw cap, round or square form bottle of 8 ounces capacity is used in conjunction with a 24 or 28 mm Polyseal plastic cap. The cap is made of a hard plastic with a conical polyethylene inner seal. No air is entrapped when a full bottle is sealed with a Polyseal enclosure. Bottles and caps may be obtained separately and are very inexpensive. When used for the B.O.D. determination no water seal is necessary. Occasionally a vacuum will be created within the bottle during a B.O.D. incubation which may cause the inner conical liner to separate when the cap is removed. This has not proved to be a serious problem. The bottles will contain about 250 ml and have been found to be blown to as close volumetric tolerance as the ordinary B.O.D. bottle.

Acknowledgment

The assistance of Ken Morikawa, Chemist, San Diego Sewage Treatment Plant, is gratefully acknowledged. The sulfamic acid was supplied by the Braun Corp., Los Angeles, California.

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Improved Membrane Filter Medium

for the Detection of Coliform Organisms

by CHARLES W. FIFIELD and CHARLES P. SCHAUFUS

Research Assoc., Dept. of Food Technology, Massachusetts Institute of Technology, Cambridge, Mass. and Chief, Bacteriology Lab., Millipore Filter Corp., Watertown, Mass. Respectively

An outstanding advance in methods applied in the field of water bacteriology during the past several years has been the development of the membrane filter technique. Of the many advantages of the technique, perhaps the most significant is the ability to concentrate bacterial organisms from very much larger and, therefore, more representative samples. The successful recovery of distinguishable colonies depends to a large extent, however, on the adaptation of a suitable medium.

In 1951, Clark, Geldreich, Jeter, and Kabler[1] advocated a two-step procedure using Albimi M medium and a modified Endo medium (EHC—USPHS Environmental Health Center) for use in the examination of water for the presence of coliform bacteria. Later, Goetz and Tsuneishi[2] suggested the use of special indicator broth media. In 1953, Taylor, Burman, and Oliver[3] modified Mac Conkey's medium for use with the membrane filter. More recently, Hajna and Damon[4] reported the adoption of buffered desoxycholate lactose broth as a one-step medium for the detection of the members of the coliform group.

Of the coliform media suggested, perhaps the most widely used today are the EHC two-step procedure and M-Hajna Damon (M-HD) Endo broth[5]; both have decided disadvantages. Because of its two-step nature (requiring an incubation period on enrichment medium prior to incubation on a selective medium), the EHC procedure is time consuming. The coliform recovery, however, is good. The M-HD Endo medium lacks clear-cut sheen differentiation of many of the intermediate coliform colonies.

Recently, an improved medium, MF-Endo was placed on the market. Preliminary tests showed the medium to be superior in several respects to existing coliform media.

This investigation was conducted to determine the recovery and selectivity of this new medium for members of the coliform group. Confirmatory tests, carried out on the sheen and nonsheen colonies produced, involved the inoculation of lactose broth and nutrient agar slants for microscopic observation in accordance with *Standard Methods* (6, pp. 395-404).

Table 1
Formulation of MF-Endo Medium

Ingredient*	Amount g/l
Tryptose	10.000
Thiopeptone	5.000
Casitone	5.000
Yeast extract	1.500
Lactose	12.500
Sodium chloride	5.000
Dipotassium phosphate	4.375
Monopotassium phosphate	1.375
Sodium lauryl sulfate	0.050
Sodium desoxycholate	0.100
Sodium sulfite	2.100
Basic fuchsin	1.050

* Ingredients are added to distilled water to which 10 ml/l of 95 per cent ethanol has been added. The medium is mixed and heated to boiling, but not autoclaved.

A coliform organism count comparison was also made between MF-Endo and M-HD broth using three different natural water sources. Further, a pure-culture study was undertaken to determine the recovery of *Esch. coli*, *Aer. aerogenes*, and five coliform intermediates.

Procedure

MF-Endo medium was made up according to the formulation given in Table 1. M-HD Endo broth was made up from a dehydrated medium. When not in use, the formulated medium was stored in a refrigerator and was not used after more than 4 days.

Before the filtration procedure, 2.0 ml of the medium was placed on an absorbent pad in a disposable plastic petri dish. Membrane filters, packed for autoclaving and sterilized at 121°C for 10 min, were employed. After filtration of the sample, the funnel was rinsed with about 25 ml of sterile water. The filter was removed and placed on the nutrient pad in the plastic petri dish. The dish was inverted and incubated at 37°C for 18 hr.

Fifty-one samples, from three sampling sites, were analyzed. Each sample was filtered in quintuplicate and,

Table 2
Confirmation of Sheen and Nonsheen Colonies Grown on MF-Endo Medium*

Sampling Point	Sheen Colonies†				Nonsheen Colonies‡			
	Confirmed		False Negatives		Confirmed		False Nega	
	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent
Charles River at Cambridge	430	86.4	75	13.6	504	96.7	17	3.3
Charles River at Watertown	457	96.0	19	4.0	400	88.7	51	11.3
Fresh Pond at Cambridge	249	99.6	1	0.4	240	69.0	10	4.0
Summary	1,136	92.3	95	7.7	1,144	93.6	78	6.4

* From 51 samples, or 255 filters.
† Total of 1,231 colonies.
‡ Total of 1,222 colonies.

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from each of the 255 filters, five sheen and five nonsheen colonies were picked and seeded in lactose broth tubes. At the end of 48 hr, all lactose broth tubes showing gas were streaked on nutrient agar slants and were examined microscopically 24 hr later. Gram-negative nonspore-forming rods, positive for gas in lactose, were recorded as coliform organisms.

It was necessary to pick all colonies while the filters were moist. The filters were then removed from the nutrient pads and dried for 1 hr on clean blotting paper, after which the sheen colonies were counted. The dried filter was placed between two pieces of glass and viewed under 16× magnification with direct lighting.

Nutrient agar plates, used as controls in the pure culture studies, were incubated at 37°C for 24 hr.

Discussion

It is imperative that any medium used for water quality analysis should exhibit a minimum of false positives and false negatives. The results of the confirmation of 1,231 sheen colonies and 1,222 nonsheen colonies are cited in Table 2. These results show a low percentage of false positives (7.7 per cent) and false negatives (6.4 per cent). Furthermore, this work was carried out in two separate laboratories, with comparable results. The coliform density at one of the Cambridge sampling points was relatively low, and occasionally colonies were picked which, when wet, appeared to show a characteristic sheen but which would not have been reported as sheen colonies when dried. Although this error resulted in a higher number of apparent false positives, it was not considered in the tabulation of the data.

As well as being selective, a good differential medium must also show a high rate of recovery of the desired organisms. A coliform count comparison on 21 samples were made between MF-Endo and M-HD broth. The count given for each sample (Table 3) represents the average of five filters. Only definite sheen colonies were recorded.

The difference in the quality and intensity of the sheen of colonies grown on the two media was immediately apparent. The MF-Endo medium removes most of the uncertainty of whether or not a colony has sheen. This fact, along with the increase in coliform recovery of approximately 35 per cent (Table 3) for these particular sampling points, indicates a distinctly superior medium.

Table 3
Comparison of Sheen Counts* on MF-Endo and HD Endo Media

Sample†	MF-Endo Count	HD-Endo Count
1	15.8	12.6
2	21.2	14.8
3	9.0	4.0
4	216.0	108.6
5	195.4	127.0
6	181.6	109.8
7	22.6	19.2
8	30.4	25.0
9	21.0	11.2
10	19.4	6.6
11	69.4	52.2
12	14.4	8.8
13	257.8	210.8
14	14.2	6.4
15	9.4	2.2
16	28.0	20.3
17	67.0	45.7
18	12.0	10.4
19	24.8	18.4
20	25.6	18.4
21	56.2	42.8
Totals	1,311.2	875.2
Per Cent	100‡	66.7

* Each figure represents the arithmetic average of the coliform count on five replicate membrane filters.
† Samples 1-15 were taken from the Charles River at Cambridge; samples 16-21 from the Charles River at Watertown, Mass.
‡ Regarded as 100 per cent recovery for purposes of comparison.

Since the entire coliform group of organisms, and not *Esch. coli* alone, has sanitary significance, a pure culture study was undertaken to determine the recovery rate of *Esch. coli, Aer. aerogenes,* and five coliform intermediates. In all cases, sheen counts on MF-Endo were compared with total counts on nutrient agar plates. The results given in Table 4 show excellent recovery rates for all cultures used.

Summary

1. An improved medium, MF-Endo, was investigated for use in enumerating members of the coliform group of organisms on membrane filters.

2. The medium produces colonies with excellent, clear-cut sheen characteristics.

3. Of 1,231 sheen colonies, picked from 255 filters, 92.3 per cent were confirmed as belonging to the coliform group. Of 1,222 nonsheen colonies, picked from 255 filters, 93.6 per cent were confirmed as not belonging to the coliform group.

4. The coliform recovery rate of MF-Endo was found to be significantly higher than the recovery rate of M-HD Endo broth.

5. Pure culture studies indicated a high rate of recovery for *Esch. coli, Aer. aerogenes,* and five coliform intermediates.

Acknowledgement

The authors wish to express their appreciation to Marcia Tully for technical assistance with the laboratory procedure and to Harold Thomas, Department of Sanitary Engineering, Harvard University, for his assistance in the interpretation of the data.

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Table 4
Recovery of Coliform Organisms on MF-Endo Medium Using Controls

	Strain						
	W-46	W-2	W-4	W-35	W-1	W-5	I-58
IMViC	−+−+−+−+−+−−+++++−−−+−−−−++						
Sheen on MF-Endo†	20.8	27.6	47.6	25.4	61.4	50.4	44.6
Count on nutrient agar†‡	21.5	28.8	52.8	26.6	59.5	51.2	50.2
Recovery—per cent	97	96	90	96	103	99	89

* IMViC refers to the combination of four tests for biochemical reactions of a coliform culture, expressed by plus and minus signs. In proper order, these are the indole, the methyl red, the Voges-Proskauer, and the citrate tests (6, pp. 390-91).
† Average of five replicate filters and plates for each coliform type.
‡ Used as control.

Maintenance Painting Procedures*

by A. L. KIMMEL

Research Chemist, the Tnemec Co., Kansas City, Mo.

MAINTENANCE painting concerns everyone, from the small home owner to the owner of the largest industrial installation. It is almost impossible to give a proper precedure for maintenance, because so many factors come into play, the chief one being economics. Problems that occur are different in almost every case, and common sense practice, therefore, is one of the best rules to follow. For further study of the problem, a list of pertinent material is included in this paper (*1-6*). Generally speaking, however, good clean surfaces and well applied coatings of the proper type will result in a satisfactory job.

In judging the durability of a paint, conditions of exposure must be considered. Because these conditions vary, standards of durability also vary. In some cases, a year's effectiveness might be excellent durability, while in other cases, 3 years' would be very poor. Experience with the local conditions is the best criterion for judging a job, with records used as a yardstick. In discussing maintenance painting procedures, surface preparation and the paint system must be considered.

Surface Preparation

When preparing steel for painting, the steel should be as clean as possible. All rust, loose mill scale, and grease should be removed. The extent to which rust and mill scale are removed depends on the surrounding equipment and cost. Sandblasting to gray or white metal is always best, though sometimes not practical. In most cases, scraping or wire brushing will be done and, if it is properly executed, it is very satisfactory. Close attention must be given to deep pits and rivet heads, because these are spots most often missed in cleaning operations. Oil and grease spots can be removed by wiping with cloths dipped in a solvent such as mineral spirits or turpentine.

For repaint work, all loose paint must be removed and the surface wiped dust free. Areas where the paint is bad down to the bare metal must be thoroughly wire brushed and spot-primed. A good general rule is that if 50 per cent of the old paint is off to the bare metal, a complete coat of primer is advisable.

Concrete and masonry surfaces should be wire brushed and then dusted to remove all loose material. If the concrete is very dense, a muriatic acid etch is usually advisable; followed by a wash with plenty of water. The surface must be dry before the paint is applied. It should be mentioned, too, that with concrete and masonry, the paint sticks by mechanical bond rather than natural adhesion. The surface, therefore, must be porous enough for the paint to penetrate and create the bond.

For repaint work on concrete and masonry, all loose paint must be removed. Oil-base paints will work well over old, tightly adhering oil base or rubber emulsion-type paints, but not over water-cement type paints. Water-cement or rubber-emulsion paints will adhere to almost any type of old paint providing it is not loose, flaky, or dusty. Repaint jobs of this type require very good surface preparation.

New plaster surfaces should be checked for alkalinity and moisture. Paint manufacturers' recommendations should be used as a guide. Repainting old plaster requires that the surface be clean and dust free, with all loose paint removed. Rough sanding or scraping should be used first to remove loose paint, and then fine sanding should be done to level the surface. Surface dust must be removed following the sanding operations.

Wood surfaces must be clean and dust free, and all dirt and loose paint must be removed. Oil spots should be cleaned off with a solvent and pitch spots should be sealed. Even the very best paints will not stick to a dirty, dusty surface, and the most economical job is the one done correctly. Money spent in proper surface preparation is insurance for an effective paint job.

Paint Systems

Primers are of more than one type. In selecting the proper one, the surface to be coated is the most important consideration.

Steel

Primer for steel should have the following characteristics:

1. Ease of application
2. Good adhesion
3. Rust Inhibition
4. Proper viscosity to produce the required film thickness
5. Durability enough to remain unaffected until the finish coats are applied.
6. A good surface on which the finish paint will adhere, and
7. Proper drying characteristics.

The purpose of the primer is to protect the steel and to afford a bond between the steel and the finish coats. Because no paint system is completely impervious to water and moisture, the primer must have enough rust-inhibitive power to eliminate rusting under blisters and the film itself. A good primer must also retard rusting on the steel when the finish system is scratched or abraded to bare metal. It should not allow corrosion to undercut the paint film. In many instances, a primer is put on and several weeks pass before the finish coats can be applied. It is a definite

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advantage, therefore, to have a primer durable enough to resist the elements. Improper drying will, in some instances, cause premature paint failure. With dusty or humid conditions, a fast-drying primer is superior to a slow-drying type. Slow-drying, oil-type primers with high penetrative action are usually best for outdoor use and for places where it is impossible to get complete cleaning of the surface.

A primer with all these features will give good service under most conditions. For highly specialized applications, it is sometimes necessary to resort to special formulations, but these cases are exceptional.

Concrete, Masonry, and Plaster

In dealing with concrete or masonry, the proper primer will depend entirely on the surface involved. Because the bond is mechanical, the prime coat should perform the following:

1. Penetrate the pores and form a good bond
2. Seal off the surface, and
3. Present a good bonding surface for succeeding coats.

The best recommendation that can be made for treating these surfaces is to follow the manufacturers' instructions to the letter. When oil-base coatings are used on concrete or plaster surfaces, especially in new work, neutralization is usually necessary. Alkaline surfaces tend to destroy the bond and will cause pulling and flaking of oil-base coatings. With most water-base or rubber-base coatings, neutralization is unnecessary. Another factor is the moisture content of the surface. Oil-base and solvent-type rubber-base coatings will not bond well to damp surfaces, although water-base coatings will. Alkalinity and moisture must always be checked before application of the prime coat.

Wood

For wood surfaces, the type of prime coat is dictated by the exposure and the finishing system. On exterior wood, a good house paint thinned with up to 25 per cent raw or boiled linseed oil is usually the best primer. It is also a good base coat for trim enamels. For interior work, a good enamel undercoat should be selected. Here again, manufacturers' recommendations are the best guide.

Finish Coats

In considering finish coats for the above surfaces, the selection will depend entirely on the conditions of exposure and the appearance desired. Because it is almost impossible to give exact recommendations on finish coats without having complete data concerning the job, no details of products will be given.

Maintenance Painting

If a careful study were made of paint jobs and the results were tabulated, the conclusions would probably show three main reasons for paint failures. In the order of their importance they are: [1] lack of proper surface preparation; [2] improper application; and [3] improper choice of material for the job. It is the foundation of a house or building which determines the life of the structure, and the same is true with paint. The best paint in the world cannot adhere to a poorly prepared surface.

Correct application is also essential. A good uniform coat of paint is always superior to a thick, irregular film because a uniform film deteriorates evenly and presents a better surface for repaint. Also, heavy, unevenly applied paint has a tendency to produce pulling and checking.

Improper choice of materials for the exposure involved is another cause of premature paint failure. Where there is any doubt, the manufacturer should be contacted. The paint manufacturers maintain laboratories for the evaluation of coatings. These facilities are for customer service, without charge, and they should be utilized.

One way to avoid an improper choice of materials is to keep good records of paint jobs. Practical experience is one of the best references and is always reliable.

Another approach that has proved itself in practice is to consider a particular job as a system rather than as individual coats of paint. If a paint job is to be durable, the primer and finish coats must work together. Here again, experience on particular jobs will indicate the effective life of the paint job.

An important point which is sometimes overlooked by the maintenance painter is the drying time of finishes. The drying or recoat time indicated on the label is usually given for standard or ordinary conditions (77°F and 65 per cent humidity). Lower temperatures or higher humidities will usually slow the drying and increase the time necessary between coats. The lifting of primer or finishes by succeeding coats can usually be directly traced to insufficient drying time between coats or to surface contamination prior to priming.

When coating machinery or equipment, it should be remembered that the painted surface will show the same defects as the unpainted surface. Paint will not fill holes, cracks, or pits, so these must be properly filled before priming or painting. If the sharp edges of previous paint are not sanded smooth, they will show through the new paint job.

Conclusions

The following points should be considered in applying new paint.

1. The cleaner or better prepared the surface, the better the paint job.
2. Good quality paint is always the cheapest in the long run.
3. For both primer and finish coats, the type of paint which is best suited for the job should be selected.
4. Past experience or manufacturers' recommendations should be used as a guide whenever possible.
5. Each coat of paint, from primer to finish, should be uniform rather than irregular.
6. Cleanliness of both structure and painting equipment is vitally necessary for a good job.

It has been the author's experience that no paint manufacturer ever tries to make bad paint. For certain jobs, however, some paints are better than others, and this selection is sometimes difficult to make. All other factors being equal, however, experience is the best criterion for judging which paint should be used.

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Inventory of 1956 Water Supply Facilities

in Communities of 25,000 and Over

by JOHN R. THOMAN and KENNETH H. JENKINS

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Inventories of water supply facilities in United States communities of over 25,000 population have been published by the USPHS for 1954, 1955, and 1956 (*1-3*), and summary statistical data for the two earlier years have been reported by Porges (*4, 5*). The report presented here gives summary data for conditions as of Dec. 31, 1956, and, for the first time, includes data from United States territorial possessions.

Porges (*5*) has reported in detail the history of the USPHS compilation and summarization of data concerning water supply facilities. As in the past, the data reported here were compiled with the active support and assistance of the various state health departments. This effective collaboration has produced consistently valuable data for many years.

The data for 1956 were summarized, using modern, high-speed punched-card tabulating equipment. This change from the use of marginal punched-card tabulating methods was carried out at this time to develop programing techniques for use in summarizing data for all water supplies in the United States. These data are currently being collected. In addition, all basic-data activities of the USPHS water supply and water pollution control program are being converted to machine tabulating procedures, with some programing for high-speed digital computers.

In changing to machine tabulating methods, certain modifications were introduced that were difficult or impossible to apply with older tabulating procedures. Consequently the earlier summary data on water supplies in communities of over 25,000 population are often not comparable with the data presented here.

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New Concepts

For purposes of this and future reports, two mutually exclusive concepts have been introduced. These are the "community" and the "facility."

A *community* is defined as a political or geographic entity having a water supply to which a census population may be assigned. It is a water-using entity and may be served by one or more water-producing facilities. A community is almost always an incorporated community as listed by the US Census Bureau.

A *facility* is a water-producing entity serving one or a group of communities. Where treatment is involved, the terms "facility" and "plant" are used interchangeably.

The use of these two concepts permits more cogent data analysis. Many communities receive water from both ground and surface sources, but the percentage of population served by ground sources—at least in the larger communities—is small. By using the "facility" concept, much of this population receiving mixed water can be assigned to either ground or surface sources. The same situation exists with regard to communities receiving both treated and untreated water, although this point is of small consequence in considering the supplies of larger communities. The use of these two concepts also permits comparisons to be made of the percentages of communities within each population group served by organized community water supplies. Although not important to the present study, this comparison is extremely relevant to summaries of small-community practices. The use of the community type of analysis has another advantage in that it permits realistic comparisons between census populations and estimated populations served.

TABLE 1

Distribution of Water Facilities According to Source, Treatment, and Ownership for Communities in the United States With Populations of More Than 25,000—1956

Supply	Communities	
	No.	Per Cent of total
Source		
Ground	125	22.4
Surface	332	59.4
Ground and surface	102	18.2
Condition		
Treated	539	96.4
Untreated	11	2.0
Treated and untreated	7	1.2
Unknown	2	0.4
Ownership		
Public	439	83.0*
Private	87	16.4*
Public and private	3	0.6*
Unknown	30	

*Percentage of total of those communities for which ownership information is given.

Analysis

This report presents only national summary data and is limited to various items concerning source and treatment, metering, certain treatment details, and needs. Data on water consumption and per capita use are being summarized separately and will be reported later.

Table 1 shows the number of communities served—by sources of water, by treatment practice, and by ownership of the system. Table 2 presents part of these same data on a facility basis and includes estimated populations served. Almost 8,000,000 persons residing in 59 communities of more than 25,000 population each were served by public water supplies from 614 separate facilities. Of the total population served, 75.5 per cent received surface water, 15.5 per cent ground water, and 9.0 per cent mixed water. Slightly less than 1.-

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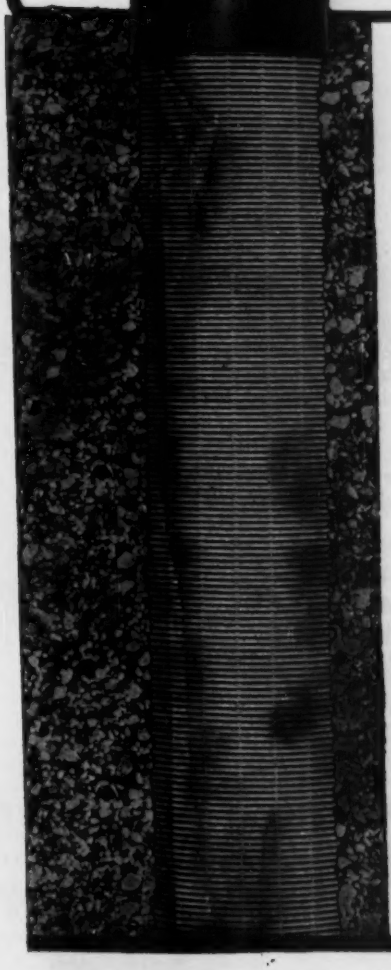

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TABLE 2

Facilities for Communities of More Than 25,000 Population According to Source and Treatment Practice—1956

Source of Treatment Status of Water Provided	Number of Facilities	Percentage of Total	Estimated Population Served	Per Cent of Total
Ground	191	31.1	13,115,087	15.5
Surface	367	59.8	63,993,810	75.5
Ground and surface	56	9.1	7,678,348	9.0
Treated	591	96.3	83,712,630	98.7
Untreated	19	3.1	968,965	1.1
Unknown	4	0.6	105,650	0.2

000,000 persons in this group of communities still receive untreated water; however, they comprise only 1.1 per cent of those served. All of the population receiving untreated water is served by ground supplies—as shown in Table 5, where data are presented on water treatment by source of supply. For practical purposes, all surface water is treated and 92.0 per cent of the population receiving ground water is receiving treated water. All mixed water supplied is treated.

Of 529 communities reporting, 439 had publicly owned water systems, 87 had privately owned systems, and three reported dual ownership. Data on metering and number of services are shown in Tables 3 and 4. For both tables, only reported cases were used. As might be expected, the percentage of services metered is greater for privately owned than for publicly owned supplies—91.0 and 84.1 per cent, respectively. Almost 84 per cent of water supply facilities for which data were available were more than 90 per cent metered. Data for other percentages are widely scattered and are shown in detail in Table 4. The relationship, if any, exisiting between per capita water consumption and percentage of metering is being studied separately, as noted previously.

Table 6 presents, in mutually exclusive groups, summary data on the various functional classes of treatment plants. These classes have the standard inventory designations—purification, iron and manganese removal, softening, or any combination of these. Disinfection as a classification is used only if disinfection as a process appears without any of the preceding three classifications. The miscellaneous category includes only those plants which fit none of the above groups—plants which have separately or in combination areation, sedimentation, chemical dosage, chlorine ammonia treatment, or corrosion control.

"Purification"—either separately or in combination with some other major plant function—generally connotes the presence of slow or rapid filters. In a few instances, plants without filters have been included when so designated by the reporting agency.

Of the total of 591 plants, over half embodied purification as a prime plant function. The largest number of plants and the largest population served—43.6 per cent and 43.8 per cent, respectively, of the total—had purification as the sole function. Disinfection—either separately or in combination with some miscellaneous unit process—comprised 34.5 per cent of the total number of plants and served 37.3 per cent of the estimated population receiving treated water. Various combinations of softening, iron and manganese removal, and purification plants together with four miscellaneous plants comprise the balance of the distribution.

Over 82,000,000 persons received disinfected water from 579 plants as shown in Table 7. This is 98.0 per cent of the population receiving treated water and 96.7 per cent of the total population served by water supplies in the group being reported. The latter figure is up only slightly—from 96.1 per cent—from data presented on conditions in 1948 (*6*). About two-thirds of the plants use only liquid chlorine as the disinfecting agent and serve 65.8 per cent of the population receiving disinfected water. The number of persons served by chlorine-ammonia disinfection is 21,700,000, which is considerably less than the almost 29,000,000 persons served in this group in 1948.

Summary data on various other unit processes used in water treatment are presented in Table 8. Gravity rapid sand filters were used in 306 plants serving over 43,500,000 persons and anthracite was used as the filter medium in 43 plants serving 4,700,000 persons. Taste and odor control measures were included in 219 plants serving almost 32,000,000 persons, with activated carbon being used in 171 plants. Some corrosion control was practiced by 216 plants serving more than 27,000,000 persons and aeration was used in 146 plants serving 19,200,000.

Table 9 presents data on chemicals used for coagultaion in treatment plants. Alum and lime were the two most commonly used materials, being employed in 300 and 242 plants, respectively.

TABLE 4

Metering and Facilities for Communities of More Than 25,000 Population—1956*

Per Cent of Services Metered	Facilities	
	Number	Per Cent of Total
0	2	0.4
1-10	15	3.1
10-20	14	2.9
20-30	8	1.7
30-40	3	0.6
40-50	3	0.6
50-60	4	0.8
60-70	3	0.6
70-80	5	1.0
80-90	22	4.6
90-99	116	24.0
100	289	59.7

*Based only on those facilities reporting metering data.

TABLE 3

Services and Meters for Communities of More Than 25,000 Population According to Ownership—1956*

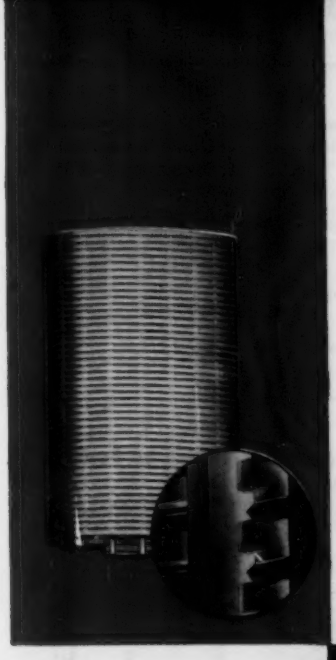
Ownership	Estimated Population Served	Number of Services	Number of Meters	Persons per Service	Per Cent of Services Metered
Public	68,454,395	13,520,185	11,374,686	5.1	84.1
Private	10,504,440	2,443,781	2,224,753	4.3	91.0
Public and Private	962,000	160,000	140,000	6.0	87.5

*Based on those reports which all data were available.

Improvements Needed

Improvements currently needed to provide adequate service were re-

off to a start



Delivering over two million gallons of water a day, this new municipal well at Xenia, Ohio—equipped with an 18" Wire Wound Cook Well Strainer—will continue to produce at a steady maximum flow for many years to come. You can count on dependable service from a Cook Well Strainer because of its exclusive self-cleaning V-shaped slot that prevents clogging and guarantees maximum delivery over long periods. Larger inside than out, the V slot allows for maximum development —permits a fast free flow of water with minimum friction loss.

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TABLE 5

Population Served by Water Systems With Various Combinations of Source Type and Treatment Practice—for Communities of More Than 25,000 Population—1956

Condition	Surface		Ground		Ground and Surface	
	Est. Pop. Served	% of Total	Est. Pop. Served	% of Total	Est. Pop. Served	% of Total
Untreated			968,965	7.4		
Treated	63,961,910	99.9	12,072,372	92.0	7,678,348	100.0
Unknown	31,900	0.1	73,750	0.6		
Total	63,993,810	100.0	13,115,087	100.0	7,678,348	100.0

ported by 450 facilities. These data are tabulated in Table 10. Multiple needs were listed by many facilities and, consequently, the data are not additive. In addition, the data cannot be quantified in terms of needed construction, because the extent of any need was not defined. The need for improvement is large, however, as only 69 facilities reported no current needs and the remaining 381 facilities reported a total of 1,121 separate needed improvements. About 58 per cent of the total needs were reported in the distribution (distribution-storage-pumping) area, the remainder being included in the source development and treatment areas. Comparisons with data on needs from prior years have not been made because of the lack of quantifying data and the difficulty in comparing the data from the same community for 2 or more years.

TABLE 6

Distribution by Functional Class of Plants Serving Communities of More than 25,000 Population—1956

Plant Classification	Plants		Estimated Population Served	% of Total Population Served
	Number	Per Cent of Total		
Purification	258	43.6	36,655,894	43.8
Purification and softening	51	8.6	9,043,752	10.8
Purification and iron and manganese removal	7	1.2	438,200	0.5
Purification, softening, and iron and manganese removal	11	1.9	1,375,600	1.6
Softening	16	2.7	1,341,403	1.6
Iron and manganese removal	29	4.9	2,556,779	3.1
Softening and iron and manganese removal	11	1.9	913,613	1.1
Disinfection only	118	20.0	12,579,508	15.0
Disinfection plus another process	86	14.5	18,648,581	22.3
Miscellaneous	4	0.7	159,300	0.2
Total	591	100.0	83,712,630	100.0

TABLE 7

Disinfectants Used in Plants Supplying Cities of More Than 25,000 Population—1956

Disinfection Agent	Plants		Estimated Population Served	% of Total Population Served
	Number	Per Cent of Total		
Liquid chlorine	388	67.0	54,025,127	65.8
Chlorine and ammonia	141	24.4	21,729,634	26.5
Hypochlorites	13	2.2	540,695	0.7
Liquid chlorine and hypochlorites	12	2.1	3,044,686	3.7
All others	25	4.3	2,674,268	3.3
Total	579	100.0	82,014,410	100.0

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TABLE 8

Treatment Process in Plants Serving Communities of More Than 25,000 Population—1956

Process	Number of Plants	Estimated Population Served
Filtration		
Rapid sand (gravity)	306	43,516,708
Rapid sand (pressure)	22	2,030,375
Slow sand	25	5,934,248
Anthracite	43	4,752,165
Softening		
Lime Soda	81	12,302,055
Cation exchange	10	1,141,700
Aeration	146	19,236,658
Taste and Odor Control*	219	31,980,462
Activated carbon	171	25,253,530
Chlorine dioxide	35	5,392,029
Others and unreported	44	6,604,256
Corrosion Control*	216	27,294,543
Phosphate compounds	83	8,093,905
Alkali for pH adjustment	154	20,612,737
Chlorine gas	12	1,181,470
Sodium silicate	7	414,030

*Figures entered under "Taste and Odor Control" and "Corrosion Control" are not additive because of the occurrence of more than one type in one plant.

TABLE 9

Chemicals Used for Coagulation in Facilities Serving Communities of More Than 25,000 Population—1956

Coagulation Agent	Number of Plants	Estimated Population Served
Alum	300	49,883,430
Iron salts	42	9,002,753
Lime	242	40,180,003
Soda ash	66	9,611,990
Activated silica	21	3,673,112
Others	24	2,760,977

TABLE 10

Improvements Needed by Facilities in Communities of More Than 25,000 Population—1956

Need	Number of Facilities*
Source, underground	85
Source, surface	85
Transmission	154
Pumping	135
Treatment	158
Distribution	230
Elevated storage	170
Ground storage	104
None	69

*Total of facilities reporting—450—is not additive, because some have more than one need.

Radioactive Rains

and Surface Water Supplies

by R. L. MORRIS

Chief Chemist State Hygienic Laboratory and Assistant Professor of Hygiene and Preventative Medicine, State University of Iowa in Iowa City, Iowa

Ground water supplies in southern Iowa and areas of several surrounding states have diminished in recent years due to drouth conditions. Therefore, increasing reliance is being placed on both dynamic and static surface supplies and a definite trend is developing toward use of farm ponds for the supply of potable water for human use as the traditional ground water supply deteriorates in both quantity and quality.

Radioactive rains and some of their effects on water supplies were reported in Massachusetts by Rosenthal[1] in 1953 and in Cincinnati by Setter and Goldin[2] in 1957. Increases in gross beta-gamma radioactivity in the air at Iowa City, Iowa, subsequent to several 1957 Nevada site detonations correlated with elevation of activity in rainfall occurring during this period. The levels of activity recorded in Iowa City were sufficiently higher than those previously reported so that the advisability of a thorough investigation into the radiological aspects of small impoundment water supplies was indicated.

Samples of all precipitation, along with daily specimens of the Iowa River were obtained at Iowa City during the months of July through October. Weekly samples were secured from several typical farm ponds in Johnson County and various other counties in southern Iowa. Samples were evaporated to dryness and counted in an internal proportional counter* according to methods recommended by the U. S. Public Health Service.[3]

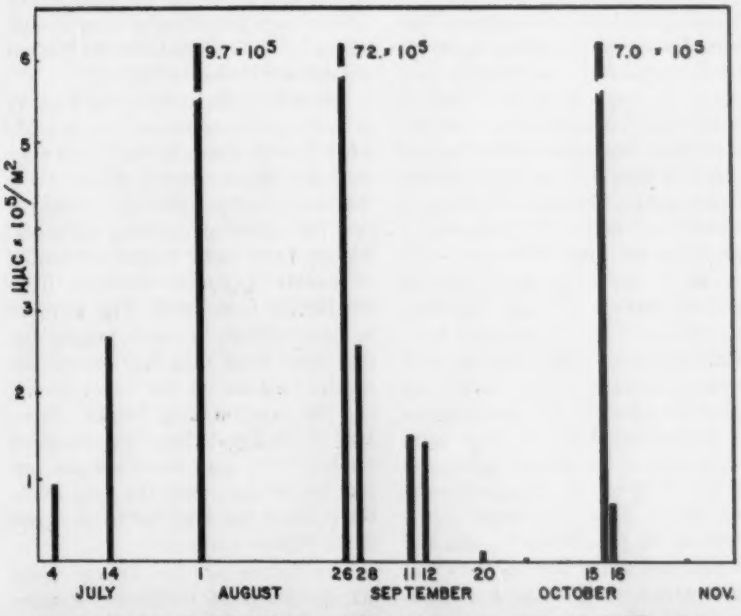

Fig. 1—GROSS BETA-GAMMA activity per square meter of significant precipitations at Iowa City causing radio activity elevations in Iowa River.

TABLE 1

Radioactive Rainfall at Iowa City, Iowa

Date (1957)	Activity (Beta-Gamma) μμc/l	Activity (Beta-Gamma) μμc/sq m	Amount of Rain, mm
7/1	2,260	4,410	1.95
7/4	7,600	91,200	12.04
7/8	18,338	91,690	5.00
7/14	38,500	274,000	7.12
7/22	3,022	55,600	18.38
8/1	78,300	967,300	12.50
8/24	17,057	21,321	1.25
8/26	14,400,000	7,200,000	0.50
8/27	110,200	55,100	0.50
8/28	6,450	258,000	40+
9/11	26,500	152,375	5.75
9/12	13,090	137,445	10.50
9/20	811	14,801	18.25
10/15	23,400	700,000	29.56
10/16	7,759	66,700	8.58

TABLE 2

Radioactivity Levels (in $\mu\mu$ c/l) of Iowa River at Iowa City, Iowa

Date (1957)	Dissolved Solids	Total Solids	University Tap Water
7/5	28.3	35.7	.....
7/6	47.1	149.7	.....
7/7	85.6	401.6	.....
7/9	65.7	162.5	.....
7/11	15.4	30.6	.....
7/16	37.1	123.1	.....
7/25	25.3	25.3	.....
7/30	38.2	54.7	.....
8/1	69.0	242.2	.....
8/3	95.6	240.4	.....
8/6	103.5	191.4	.....
8/8	70.2	97.0	.....
8/12	57.1	75.4	.....
8/14	28.0	71.6	40.1
8/22	10.6	48.0	11.3
8/26	95.9	.....	9.2
8/27	64.9	.....	73.6
8/28	150.9	895.9	74.1
8/29	224.0	366.0	221.1
8/30	106.5	169.1	74.5
8/31	67.3	102.1	93.0
9/4	69.4	69.4	46.1
9/10	44.3	54.5	44.3
9/12	135.0	311.0	162
9/13	52.9	105.2	53.9
9/24	30.3	39.4	.....
9/25	160.5	184.4	16.9
9/26	175.6	180.9	18.1
9/27	36.7	41.0	24.4
10/14	13.6	18.6	15.0
10/15	53.2	114.5	.....
10/16	37.7	150.1	51.6
10/18	84.6	121.5	64.6
10/20	52.1	101.7	.....
10/27	20.3	42.2	.....

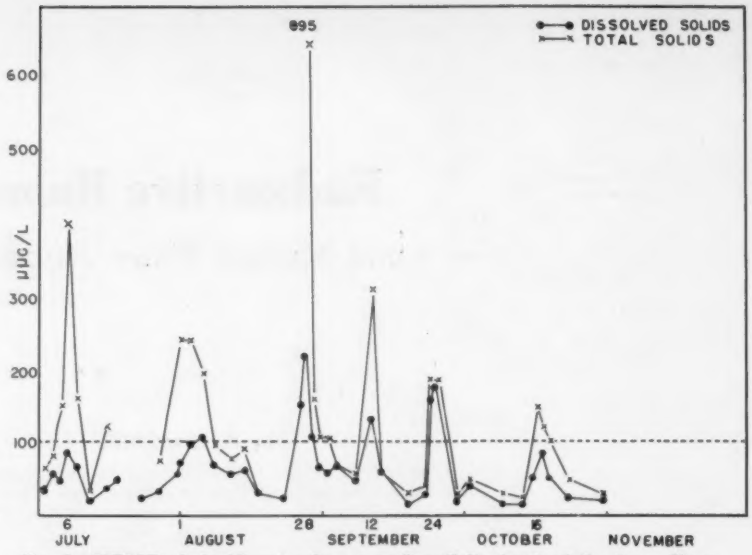

Fig. 2—EFFECT of significant rains on radioactivity level of the Iowa River.

National Bureau of Standards Handbook 52[4] covering maximum permissible concentrations of radioisotopes in water states, "10^{-7} μc/ml beta or gamma emitters are believed to be safe for exposure to any of the radioisotopes for periods of a few months." This level applies to all isotopes except Ra^{226}, Pu^{239} and Sr^{90}, all of which have significantly lower maximum permissible concentrations. It is recommended by Handbook 52 that average operating levels should be kept as far below these values as possible, and not above them for any extended period of time. The value of 10^{-7} μc per ml was recalculated to be 100 $\mu\mu$c per liter and this value has been assumed as the acceptable level for both river and impoundment waters when anticipated for human use.

Table 1 shows the amount and activity of rains during July-October 1957; Fig. 1 presents the gross beta-gamma activity per square meter of those significant precipitations causing activity elevations in the Iowa River. This latter value is a function of the depth of rain which fell and its radioactive content per volume.

Rains having above-normal activity were invariably preceded by air activity levels several times the natural background. These air level increases usually could be correlated with recent bomb detonations in Nevada, and decay data on the collected rain samples showed the isotopes to have half-lives of from 5 to 9 days. Ten significant rains were recorded in this four-month period and their effect on the Iowa River is shown in Fig. 2.

Seven periods of above-normal radioactivity in precipitations were recorded, respectively, on July 4, July 14, Aug. 1, Aug. 26 and 28, Sept. 11 and 12, Sept. 20, and Oct. 15 and 16. Six of these incidents were evidenced by marked rises in Iowa River radioactivity levels. Results of pertinent dissolved and total solids radioactivity analyses of the Iowa River are given in Table 2. Specimens were collected and run daily, but only relevant changes in activity are recorded here.

Unfortunately, river samples were not run subsequent to the rain of July 14, but the effect of this precipitation was demonstrated by the high beta-gamma level of the Beaver farm pond on July 15 (Fig. 3). Figure 2 indicates that a large percentage of the activity in the Iowa River is contained as suspended solids and suggests that sedimentation, coagulation and filtration would effectively remove major portions of the total activity. Analyses of the Iowa University tap water, which is the result of this type of treatment, bear out this premise.

The increase of activity in the Iowa River was extensive and sharp following significant rains, but the duration above the maximum permissible concentration of 100 $\mu\mu$c per liter was quite short. This is probably due to the narrow restricted watershed of this river and its rather rapid rate of flow. A total of 7 days out of four months were recorded above 100 $\mu\mu$c per liter for dissolved solids, with 28 days above this level for total solids. The average gross beta-gamma counts based on daily records for individual months are shown in Table 3.

Interest in the radiological aspects of farm ponds developed on July 15, when several ponds around Iowa City were tested and found to be well above the maximum permissible concentration for continual drinking purposes. Figure 3 and Table 4 give the results of weekly specimens obtained from the Beaver farm pond. The increase in gross activity is much greater for this farm pond than was shown for similar periods on the Iowa River, and the duration is far longer. From July 15 through October the dissolved solids activity was above 100 $\mu\mu$c per liter for 60 days, with the total solids being above this level for 64 days out of the 80 days covered.

The failure of the Beaver pond activity levels to evidence the rains of August 1 and September 20 is prob-

* Manufactured by Nuclear Measurements Corp.

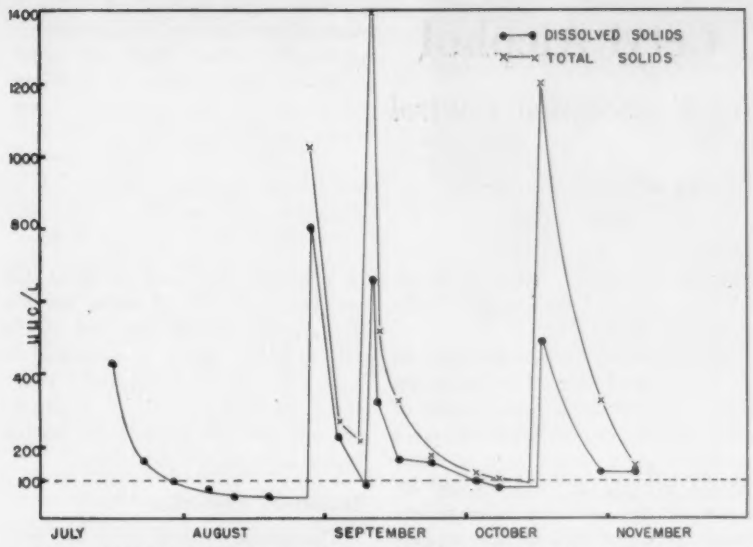

Fig. 3—EFFECT of significant rains on radioactivity level of the Beaver farm pond.

TABLE 3

Monthly Averages of Daily Radioactivity Levels of the Iowa River (in $\mu\mu$ c/l)

Month (1957)	Dissolved Solids	Total Solids	University Tap Water
July	35.4	78.3	.....
Aug.	62.0	138.0	51.6
Sept.	54.5	80.7	40.2
Oct.	27.8	48.0	29.3

ably due to the spotty character of summer rains, as it was noted that some of the farm ponds being studied did show activity increases following these two precipitations. Table 5 gives some beta-gamma levels obtained on farm ponds in areas other than Iowa City.

Relatively large algae growth existed in the Beaver pond and was identified as *Ulothrix* and *Microspora* primarily. Table 4 shows that the algae concentrates significant amounts of the activity. Cattle wade in the edges of these ponds and stir up the border algae growth extensively. Their drinking water quality is best illustrated by the activity in the total solids after agitation (Table 4). Obviously, a cattle watering supply of considerably lower activity could be provided by overflow into a watering trough below the pond dam.

Some evidence has been accumulated to show that high winds effect mixing of the algae particles and the supernatant water causing abnormally high total solids activity at times. These data indicate that this activity increase in turbid farm pond samples is primarily due to the algae particles and not by stirred up bottom sediment.

The frequency, duration and concentration of radioactive fallout particles in Iowa farm ponds is sufficient to warrant careful consideration regarding their use as sources of potable water supply when evaluated according to current National Bureau of Standards maximum permissible limits.

Studies of specific concentrations of the more stable isotopes in these ponds are contemplated.

TABLE 4

Radioactivity Levels of Beaver Farm Pond (in $\mu\mu$ c/l)

Date	Before Agitation		After Agit.	
(1957)	Diss. Sol.	Tot. Sol.	Tot. Sol.	Algae
7/15	438	.....	.....	.....
7/21	159	159	.....	.....
7/26	101	.....	.....	.....
8/5	81	.....	.....	.....
8/11	66	72	.....	.....
8/18	64	64	.....	.....
8/28	800	1,023	.....	.....
9/3	225	244	.....	.....
9/9	93	213	.....	.....
9/11	653	1,400	1,418	.....
9/12	327	523	914	.....
9/16	166	329	595	1,875
9/23	161	169	332	1,900
10/2	100	108	132	336
10/7	82	93	586	913
10/16	490	1,180	1,400	.....
10/28	123	325	460	.....
11/6	125	125	213	.....

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1. Rosenthal, B. L., "Radioactive Rainfall Found in Massachusetts," *Sanitalk* (Nov. 1954).
2. Setter, L. R., and Goldin, A. S., "Radioactive Fallout in Surface Waters." *Ind. Eng. Chem.*, 48: 251 (Feb. 1956).
3. Robert A. Taft Sanitary Engineering Center, "A Method for Determination of Radioactivity in Water" (May 1954).
4. National Bureau of Standards, U. S. Dept. of Commerce, Handbook 52, "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," pp. 10-12 (Mar. 1953).

TABLE 5

Miscellaneous Farm Pond Radioactivity Levels (in $\mu\mu$ c/l)

Date (1957)	Location	Diss. Sol.	Tot. Sol.
9/17	Albia I	135	182
10/1	Albia I	18	25
9/17	Albia II	152	206
10/1	Albia II	47	47
9/18	Bedford I	122	147
9/18	Bedford II	121	133
9/19	Indianola I	100	105
9/19	Indianola II	155	224
10/2	Indianola I	58	58
10/2	Indianola II	51	68

Cetyl Alcohol

for Evaporation Control

by WILLIAM A. HEATH
Surrey, England

Water losses thru evaporation—about 13 cubic miles being lifted from the earth's surface every 24 hours—are being reduced in many parts of the world following extensive work by the Commonwealth Scientific and Industrial Research Organization (C. S. I. R. O.) in Melbourne, Australia.

Co-operating with experimenters in other parts of the British Commonwealth, notably Kenya (East Africa), and with a British company, Price's Limited in Bromborough, the C. S. I. R. O. has developed two methods of filming reservoirs and storage tanks with a skin of cetyl alcohol less than one millionth of a millimeter thick. This skin of cetyl alcohol (hexadecanol), product of the sperm-whale's oil commonly used in manufacture of cosmetics and pharmaceutical products, can be penetrated by oxygen and rain; it has no effect on the water it protects against wind and sun, and is harmless to acquatic life.

Application from Rafts

Trials carried out in Kenya by F. Grundy, of the East African Meteorological Department, Nairobi, were described in Water & Sewage Works of August 1956.

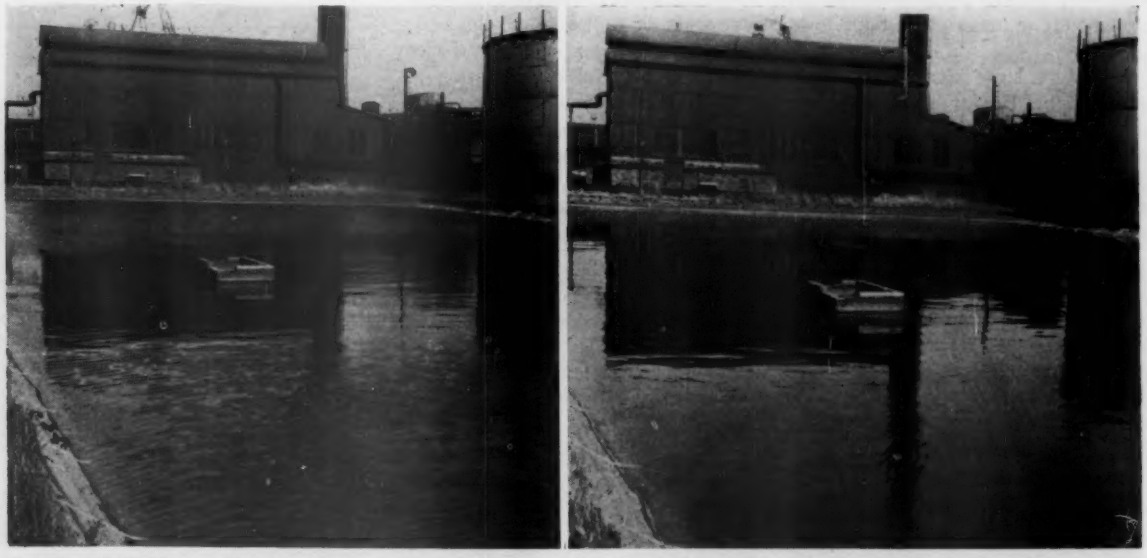
These African trials were based on the raft method of misting reservoirs. Rafts, each containing one pound of cetyl alcohol in small pellets, were anchored one to every acre of water surface area. Film was formed by action of the water on the pellets which were enclosed in fine copper-mesh baskets in the raft framework.

Rafting has also been tried in Australia, where it has proved of particular value to the sheep and cattle farmer who usually depends on a station tank, dug in the catchment area, for his water supplies. Until now station tanks had to be excavated to a depth of 14 feet to allow for the quantities of water lost because of evaporation; and the deeper the tank, the greater the cost. Now that evaporation losses can be cut, the tanks can be dug to a less costly depth, the number of tanks on a station can be economically increased, and therefore the size of the herd supported increased.

Field trials in Australia have shown that savings of up to 70 per cent can be achieved at a cost of about $27 per year per acre of water surface. This figure includes the cost of the raft — $75 — which is estimated to have a life of five years, and a year's supply of cetyl alcohol, i.e., 8 pounds per acre per year at $1.40 per pound. Labor charges are additional.

Subsurface Application

The second method which has been successfully tried out in Australia aims at conserving water supplies in larger reservoirs. It takes advantage of two of the factors which cause evaporation, sun and wind. Flakes of cetyl alcohol are dissolved in a solvent and released in a series of small drops below the water's surface. The drops rise to the surface where the solvent evaporates in the heat of the sun, leaving the film. This is blown across the reservoir until the whole surface is covered. Since effective filming depends on the wind spreading the cetyl alcohol skin, the dispensers containing the solution are fitted with wind-operated valves, ensuring that the solution is only released down-wind, thus preventing wastage.



WATER SURFACE, unruffled by wind, shows extent of spreading of chemical film in experimental tank.

Drips of solution are released at depths between one inch and 12 inches below the water surface. Dispensers are both shore-based and floating on rafts. Treatment is at the rate of 8 to 9 pounds of cetyl alcohol per square mile per day.

This method has been applied successfully at Broken Hill (Australia) using flake cetyl alcohol dissolved in a hydrocarbon solvent with a boiling point of 140°C. A small quantity of methylated spirit was added to increase solubility of the cetyl alcohol, the final solution being made up of 10 per cent cetyl alcohol, eighty per cent solvent (Shell X95) and 10 per cent methylated spirits.

Losses from this reservoir, the main water supply for Broken Hill, are normally four times consumption and in the dry season evaporation wastage is 80 to 100 million gallons a week, against consumption of 20 to 25 million gallons. The solvent method of application of cetyl alcohol has reduced wastage by 37 per cent, using four dispensers per mile of reservoir perimeter.

Cetyl Alcohol Pellet Manufacture

Biggest problem in the fight to cut evaporation losses was the production of suitable forms of cetyl alcohol; solid blocks and small flakes were used in the rafting trials in Africa and Australia. The flakes gave a satisfactory film, but were so fragile that they disintegrated in the rafts and were wasted.

Production of beads in Australia resulted in only a small percentage of each batch coming within the size range required for effective operation.

That was the situation when the C. S. I. R. O. approached the British firm Price's Limited with a request to produce beads of a standard size between 2 and 4mm in diameter.

The firm devised a method of meeting this requirement; liquid cetyl alcohol was forced thru an aperture so that it formed a liquid jet. This was subjected to sonic vibration which separated it into liquid particles which solidify as they travel through the air and are collected as uniform sized beads.

As the effectiveness of the cetyl alcohol film depends on the material used, the C. S. I. R. O. has decided to protect users by awarding a certification mark to manufacturers who succeed in meeting the stringent specifications. The mark is known as SIRO-SEAL and the first company in the world to be awarded it is Price's Limited.

ALMOST PERFECT REFLECTION, blurred only by wind, shows water surface is filmed. Technicians are experimenting with cetyl alcohol at factory of Price's (Bromborough) Limited, Cheshire, Eng.

Formula of the Cetyl alcohol beads awarded the certification is:

Cetyl alcohol—not less than 80%
Octadecanol (Stearyl alcohol)—not more than 10%
Tetradecanol and dodecanol—not more than 5% together
Alcohols of chain length less than 10—not more than 0.5%
Unsaturated alcohols—not more than 4%
Iodine value—less than 3
Acid value—less than 0.3
Saponification value—less than 0.5
Hydroxyl value—225 to 230
Melting point—47-50°C.

The use of cetyl alcohol is a proven technique for the reduction of evaporative losses from open bodies of water. The effectiveness of this treatment, however, depends on the application and maintenance of the film over the entire body of water. The engineering problems connected with meeting this requirement have for the most part been solved now.

DEMARKATION LINE between relatively smooth surface and marked ripples shows area covered by film.

Saline Water Conversion

by SHEPPARD T. POWELL
Consulting Engineer, Baltimore, Md.

Water consumption in this country has increased more than sevenfold since 1900 and it is reliably predicted that by 1975 the national water requirements will be doubled. This is a sobering prospect which cannot be ignored. Even in areas where large volumes of water are available, shortages are being experienced due largely to concentration of industries and population, and to the ever increasing demand for irrigation water.

A rational and coordinated federal and state water policy can do much to solve the country's water needs. This can be effected by a number of corrective measures, some of which if adopted, could avoid or minimize water shortages in many places. Particular reference being made to the conversion of sea water and other available saline sources into acceptble fresh water.

Over the ages, mankind has recognized that the production of fresh water from the sea offered one of the greatest economic benefits and, if accomplished successfully, would revolutionize living conditions where fresh water is now unavailable or in short supply.

Studies Being Made in 30 Countries

In recent years there has been expanding interest in methods of desalting water and at the present time studies are being actively pursued in more than 30 countries throughout the world. The first intensive and coordinated research and development program in this country was initiated in 1952, when the Congress of the United States passed Public Law 448. The purpose of this legislation was to develop low cost salt water conversion processes through research grants and contracts. To carry out the provisions of the Act, the appropriation of $2,000,000 was authorized for a five-year period. Congress designated the Secretary of the Interior to carry out the terms of the Act, and the Secretary created the Office of Saline Water to plan and conduct the program. In June, 1955, Congress extended and expanded the actively to include some work in Government laboratories and increased the total authorization to $10,000,000 over the period from 1952 to 1966. So far only $2,850,000 has actually been appropriated.

The widespread interest in desalting water is illustrated by the fact that since the Saline Water Program was initiated in 1952, there has been received more than 600 suggested schemes, all of which have been evaluated. Out of this flood of lay and technical ideas, 58 possessed sufficient scientific merit to justify the awarding of research and development contracts.

Five General Process Groups

The processes showing potential merit so far fall in five general groups, in addition to basic and exploratory research on entirely new ideas which constitutes a sixth group. Emphasis and effort are being concentrated on the ones indicating most promising results.

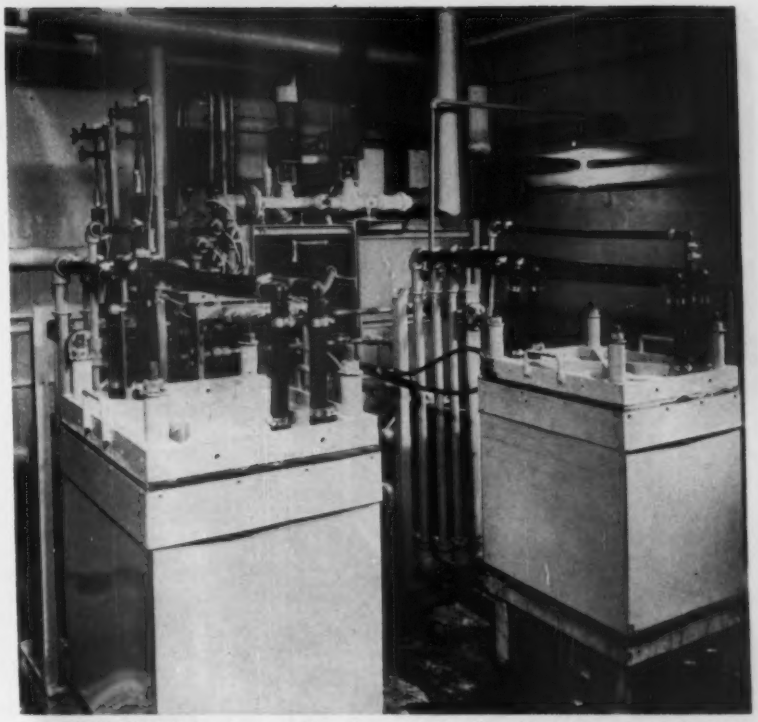
As a result of the contract work so far one pilot plant has been field tested and is in commercial production, two pilot plants are under field test in North Carolina, while a third group of smaller pilot plants is being installed. Four processes are in advanced laboratory stage and will reach pilot plant phase within the next year and several new processes are being advanced in the laboratories.

Most of the demineralization processes known are now under study or are in the experimental stage of development by scientists in at least twenty countries, in addition to the investigative projects in the United States. The five general types of conversion processes include distillation by various types of evaporators, solar distillation, freezing methods, membrane processes including osmosis and electrodialysis, and solvent extraction. Other processes under exploratory research involve complex chemical and thermodynamic reactions. The present state of practical application of distillation and the other more advanced processes indicate that much more exploratory and basic research in quest of wholly new approaches is justified if water at the low costs needed for municipal and irrigation uses is to be had.

Solar Stills

Production of fresh water from saline sources by solar stills is the simplest type of conversion apparatus. The sea water to be evaporated is run into shallow compartments and the vapor produced by the sun's rays is condensed by a cover made of glass or plastic material. The condensation, which is free of solids, is collected by appropriate troughs. This type of apparatus has application in many places in the world where there is a high percentage of sunlight during the year, and the conversion process, therefore, has some application in certain areas in the United States. This type of system has wide application where low quantities of water are required.

As with other processes, the cost of solar distillation varies greatly and some investigators believe that with further research water might be produced as low as fifty cents per thousand gallons. At present, however, costs are very much higher, probably of the magnitude of two dollars per thousand gallons, or more.



BRACKISH WATERS such as well water used at a New York Thruway restaurant near Victor has undesirable salts removed by this Ionics Inc. equipment rated at 12,000 gpd.

Electrodialysis

Conversion by electrodialysis is based on the removal of ions by passage of the water through specially prepared membranes. The mechanism by which the process functions involves complex electrochemical principles and is not subject to discussion here. Although this process can convert sea water to fresh water, it is uneconomical at present for such service, except under special conditions. Undoubtedly, the future application of such processes will be more adapted to brackish supplies than to sea water. Fairly extensive research work in this field of endeavor has been conducted by numerous groups, both in this country and abroad. It is expected that such research will be continued.

A number of small capacity plants of this type have been installed and operated successfully for several years. It has been reported recently that a large capacity system of this type has been authorized by a group in South Africa. The designed capacity of the plant will be nearly 3 million U. S. gallons daily. The source of the saline water will be water pumped from gold mining operations. It is predicted that the saline salts which are principally sodium chloride will be reduced from 4000 parts per million to 500 ppm. The estimated cost of the conversion will be about 29 cents per 1000 gallons, under the local conditions. This is a low cost treatment and, if realized, should be of interest.

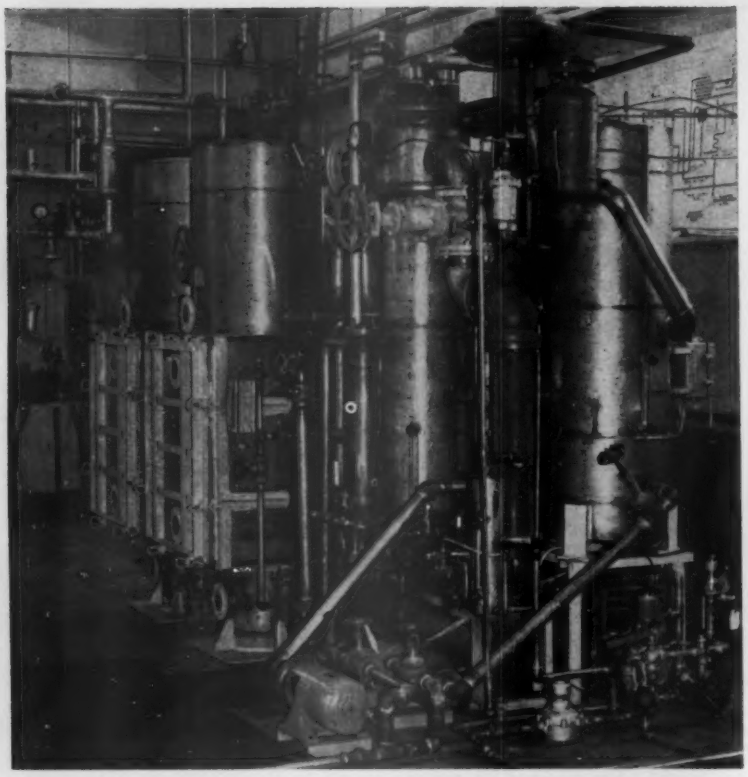
A more recent application is the small commercial unit shown in the photograph. This unit, purchased for $42,500 is expected to produce water under the local operating conditions at a cost of $0.50 per 1,000 gallons. The unit removes about 200 pounds of salts from a throughput of 12,000 gpd of water reported to be about one-fourteenth the mineral content of full-strength sea water.

Freezing

Research for desalting of sea water by the freezing method is continuing and has promise of application under specific conditions. It has been developed to a stage which should warrant a pilot plant of small capacity within a year. The process consists merely in lowering the temperature of the saline water to form ice crystals which are free from salts, subjecting the crystals to successive washings with fresh water to remove entrained salts. One investigator developing a particular freezing cycle has estimated a cost of about $1.00 per 1000 gallons of fresh water having a salt content of 500 parts per million. Comparing this figure with a predicted cost of $1.00 per 1000 gallons, or less, for distillation of sea water by multiple effect evaporators, or less if by-product energy is available, indicates that greater development of the freezing process may make it competitive with evaporators.

Evaporators

One of the most promising sea water conversion systems now available for the production of relatively large volumes of fresh water is by evaporators or distilling apparatus, integrated with the generation of electric power by steam stations. The fundamental principle of the operation of such equipment is well known, and fresh water has been produced by evaporation for numerous services for many years. Relatively high capital and operating costs have inhibited widespread adoption of such processes for large-scale operation. Using conventionally designed apparatus, the present cost of producing fresh wa-



EVAPORATOR installed at the Castle Harbour Hotel, Tucker's Town, Bermuda and manufactured by Maxim Silencer Co. has a rated capacity of 20,000 gpd.

ter from sea water varies from $2 to $3 per 1000 gallons without credit to power generated or other benefits. By much further research and developmental work and ingenuity in design of equipment, these costs can be greatly reduced. Reduction in cost can be effected principally by substituting less costly metals for special alloy materials now generally used, and by controlling scale formation; namely, preventing deposits on the heating surfaces and devising means for higher heat transfer rates and other improvements. It is reliably estimated that the cost of fresh water from the sea can be reduced to between 50 and 60 cents per 1000 gallons. This is equivalent to approximately $163 to $196 per acre foot. It is not unreasonably optimistic to predict that numerous figures quoted can be still further reduced. This will depend upon the designed capacity of the installation, utilization of by-product heat energy, possibly recovery of salable by-product from the concentrated brines, and other intangible credits.

A 2.7 mgd combined water distillation and electric generating steam plant was put into operation on the island territory of Aruba, Netherland Antilles. This plant is to supply the island population of 55,000 and the American owned Lago Oil & Transport Co. refinery which is one of the largest in the world.

The Aruba Government estimates the production cost of converted water at about $1.75 per 1000 gallons but actual figures have not been released. Increased electrical output is expected to lower water distillation costs further. This new surplus of potable water and electricity will assist in the rapid development of the island.

The Aruba installation is now the largest of its type. The Kuwait plant serving the American Oil Co. with converted waters of the Persian Gulf is now the second largest.

The photo illustrates a multiple-effect evaporator. A similar installation exists at St. John, Virgin Islands rated at 30,000 gpd. These installations replaced catchment basins for conserving rain water and a need for barging fresh water to the respective areas during the dry season.

Operating costs of evaporators rise only slightly with increased salinity. Equipment for converting saline water by this method is adapted or modified to make maximum use of any available heat source.

Large Scale Costs Unknown

In summary, the exact cost of producing fresh water from any saline sources on a large production scale; namely, 10,000,000 gallons per day or greater, is still not known. The reason for this is that no plant of this kind has yet been constructed or operated, and it is obvious that costs are influenced by the size of the installation. Until such installations are in actual operation, and cost data are assembled, figures quoted must be considered as estimates only.

As an illustration, it has been predicted that fresh water can be produced from sea water to as low as 50 cents per 1000 gallons, with one evaporation process based on a plant having a capacity of 10,000,000 gallons per day, whereas the cost at the present time with conventional plants of much lower capacity ranges from $2 to $6 per 1000 gallons. Similar reductions in cost of operation on the same basis will undoubtedly be possible with other types of conversion plants when the systems are properly designed and are of a sufficiently large capacity to take advantage of savings resulting from the larger capacity installations.

However, we do not have positive asurance that distillation alone will provide fresh water at much less than $100 an acre foot or about 32 cents per 1000 gallons. Instead, much greater exploratory and basic research will be needed if we are to expect large quantities of converted sea water at costs that are economically feasible for agricultural and most municipal uses.

Saline water conversion may be necessary to supply the seaboard communities of United States. The rising costs for developing fast depleting fresh water supplies may soon make demineralized processed water competitive.

Expanding and Improving

Water Distribution Systems

by DONALD E. STEARNS
Consulting Engineer, Cazenovia, N. Y.

Water usage is showing a rapid increase year after year, although an inventory by the Business and Defense Services Administration shows that forty-two per cent of the public water supplies are inadequate in one way or another. It is apparent, therefore, that there is much work ahead in meeting expanded and rapidly increasing domestic, commercial and industrial requirements in both urban and suburban areas.

There are many times when it is not possible to meet local water needs because of an inadequate water distribution pipe network even though water resources are adequate. Many pipe networks are now having artery trouble. This may be due to tuberculation that has reduced main capacity; to undersized pipes in the initial system; to over extension of pipe mains; or to ineffective distribution systems either lacking in design or poorly designed.

Planning an economical pipe main strengthening program is a difficult task and calls for a careful appraisal of many factors and not simply adding another main to the system. Factors to be considered are: present condition of the pipe mains including valves and fittings; present and predicted future needs to be served; supply mains, pumping facilities and storage facilities now in service; and, of extreme importance, financial considerations.

Fig. 1—PORTABLE Bristol pressure recorder
Used to plot continuous record of pressures at selected points on the system

It is the purpose of this article to outline an approach to the problem of distribution systems strengthening that the author has used and developed over the past 20 years and has applied to some 50 water systems both large and small. The chief objection to precise methods of studying distribution systems has been the desire to find a simple direct approach that could be readily applied. At best, it may be said, no method has been devised that permits a true hydraulic analysis of a pipe network without considerable expenditure of effort. The use of nomographs, the reducing of the elements of the system into convenient working forms, field testing of the elements of a water system, as well as the considered judgment of the person making the analysis all play an important part in the task.

Field Data Required

Before any analysis can be made it is necessary to acquire considerable field data and to carry out certain basic field tests that furnish the necessary basic data for a hydraulic study. We accomplish this by first studying general maps of the distribution system, locating the main feeders, determining points in the system where pressure observations can best be made and points where drafts on the system may be required.

In our studies portable Bristol pressure recorders are used to plot a continuous record of pressures at these various selected pressure stations. See Fig. 1. These recorders have 2 speedclock driving mechanisms so that either a 24 hour pressure chart may be obtained or an accelerated recording made, the latter

Speaking of Water Mains...

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

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Long Service Life--

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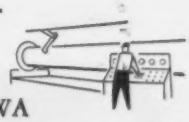
Tested for Strength--



Every length of steel pipe is hydrostatically tested at the shop in accordance with AWWA specifications—usually to double the working pressure. What's more, steel pipe can withstand from 3 to 4 times the working pressure before bursting. And steel pipe safely resists water-hammer, shock loadings, and surge.

Elasticity--

Steel "gives" under stresses that would cause more rigid materials to crack or break. Steel pipe can "absorb" traffic vibration as well as shock due to explosions and earth tremors. Its elasticity allows it to transmit much of the load to the surrounding earth. This is not true of rigid-walled pipe.

Leakproof Joints--

100 pct bottle-tight joints are a practical reality with steel pipe, whether mechanical couplings or welds are used. That means no water wastage, no costly washouts. And you needn't fear contamination of the contents due to infiltration from without. Joints are quickly made, they're permanent, and strong.

Easy to Install--

This drawing compares a single 40-ft length of steel pipe with 16-ft lengths of rigid-walled pipe of the same inside diameter. The steel pipe has thinner walls and a smaller outside diameter; weighs only about one-fifth as much per ft of length. Results: the steel pipe costs less to ship, to handle, and to lay. It requires a smaller ditch, fewer bell holes, fewer joints—only 132 per mile.

Corrosion-Resistance--

Modern methods of lining steel pipe with hot-spun coal-tar enamel make it immune to corrosion and incrustation. There is no known time limit to this protection. Many tar-enameled lines have been in service for upwards of fifty years. Coal-tar enamel provides the smoothest surface obtainable, assuring high flow coefficients year after year. Coatings and wrappings protect the pipe from moisture, acids, and alkalis.

Beam Strength--

Steel pipe has the structural strength that is characteristic of tubular steel. It can span long washouts; is often handled in multiple lengths during installation. And steel pipe can stand up under the weight of heavy cover.

Widely Used--

Some recent users of Bethlehem Steel Pipe: New York City, New Orleans, Philadelphia, Savannah, Decatur, Cincinnati, Atlanta, Omaha, St. Paul, Colorado Springs, and Boston. Further proof of the superior qualities of steel pipe is its use in thousands of miles of large-diameter gas and oil lines, as well as in high-pressure penstocks throughout the world.

For further information about steel water pipe, kindly contact the nearest Bethlehem sales office.

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BETHLEHEM STEEL

lending itself more readily to interpretation.

While the pressure recorders are in service, drafts are placed on the pipe network at various locations so that measured flows may be taken and the variation in resulting pressures noted at the locations of the portable recording gages. Instead of the conventional Pitot Tube we have developed flow orifice nozzles that have been calibrated and are capable of a wide range of flow measurements. A single nozzle will record accurately flows from 25 to 600 gallons per minute. Four sizes of stainless steel orifice plates are used on the nozzles to accommodate this wide range of flows. For heavy drafts, two nozzles may be used on a single hydrant and also more than one hydrant can be flowed simultaneously. Figure 2 shows a nozzle in use.

Our experience has led us to test pipe networks in their entirety rather than individual pipe lines. We believe that the action of a pipe network with various pipes acting together gives much more significant and accurate results than single pipes. We feel that testing a pipe network in its entirety reflects the action of valves, fittings, appurtenances and other restrictions that may have a marked effect on the flow pattern. We have even found, as a result of this method of testing, the existence of mains not shown on existing maps and also pipe sizes that differed from the map size.

Altimeter Survey

After the actual flow tests and pressure recordings have been made, we then make an altimeter survey of the pipe network to determine elevations of points where pressures were recorded, hydrants where flows were made and points where residual line pressures were taken as a part of the field testing program. We use a matched pair of Wallace and Tiernan altimeters for this purpose; these are capable of indicating changes in elevation of about 2 feet. By carefully following the variation in temperature and atmospheric conditions even more precise results may be obtained. We find that the 2 foot accuracy is sufficient for the studies to be made and consistent with the other basic data that enter the study.

Our general procedure on an altimeter survey is to locate one altimeter at a Geodetic Bench Mark in the geographical area of the survey, and then to carry the other altimeter by car to the various points where elevations are desired. One observer reads the altimeter at the Bench Mark at frequent intervals and records both the time of observation and reading, while the other observer takes readings at various points on the pipe network. This makes it possible to record changes in atmospheric conditions while the survey is being made and to make corrections therefor. Often an entire community may be covered in a half day by two men while such a survey might require several days with a field party by other conventional methods. Elevations of storage facilities, pumping facilities, gravity supplies, etc. are readily obtained by this method as a part of the survey.

Fig. 2—NOZZLE for determining flow rate

Determining The "C" Value

With basic information on pressures, flows and elevations it is now possible to make office studies to determine the hydraulic behavior of the system being studied. Such studies reflect the present day condition of the pipes that make up the network. Computing the so called "C" value of the pipe network is the most common index of present condition. Although a "C" value of 120 is common for new pipe installations we find that a "C" value as low as 60 is common to many distribution systems that were installed between 1880 and 1900. Most of our present distribution systems in Central New York State were constructed the latter part of the 19th century.

To determine the "C" value of the pipe network, we first assume that all pipes in the system have a "C" of 100. We then reduce all pipes in the network to an equivalent length of 8 in. pipe or 12 in. pipe to facilitate further studies and to reduce the amount of computation necessary. It is now possible to determine the head loss across the pipe network for the above assumed pipe condition by means of nomographs designed for the purpose. Figures 3 & 4 are the nomographs used. These nomographs are based on the Hardy Cross method of flow analysis. A random flow is assumed to be taken off at a given point and the distribution of the feed in the various mains in the system is assumed. In other words if 1000 gallons per minute is being taken from the system at some point, a flow or feed of 1000 gallons per minute is distributed into the system over and above system leakage and other water usage beyond that being taken off at the point of draft. An analysis is then made and the heads balanced for any path of flow thru the pipe network until the head loss by any path thru the system is an equal or fixed quantity. This requires time and considerable judgment in order to keep the necessary office work to a minimum. It is true, however, that the answer obtained reflects a true hydraulic condition for the assumed flow.

Comparing the results for an assumed flow with the head loss obtained for an actual flow in the field offers a basis for determining the actual "C" value of the pipe network. There are many factors that may cloud the issue and complicate this

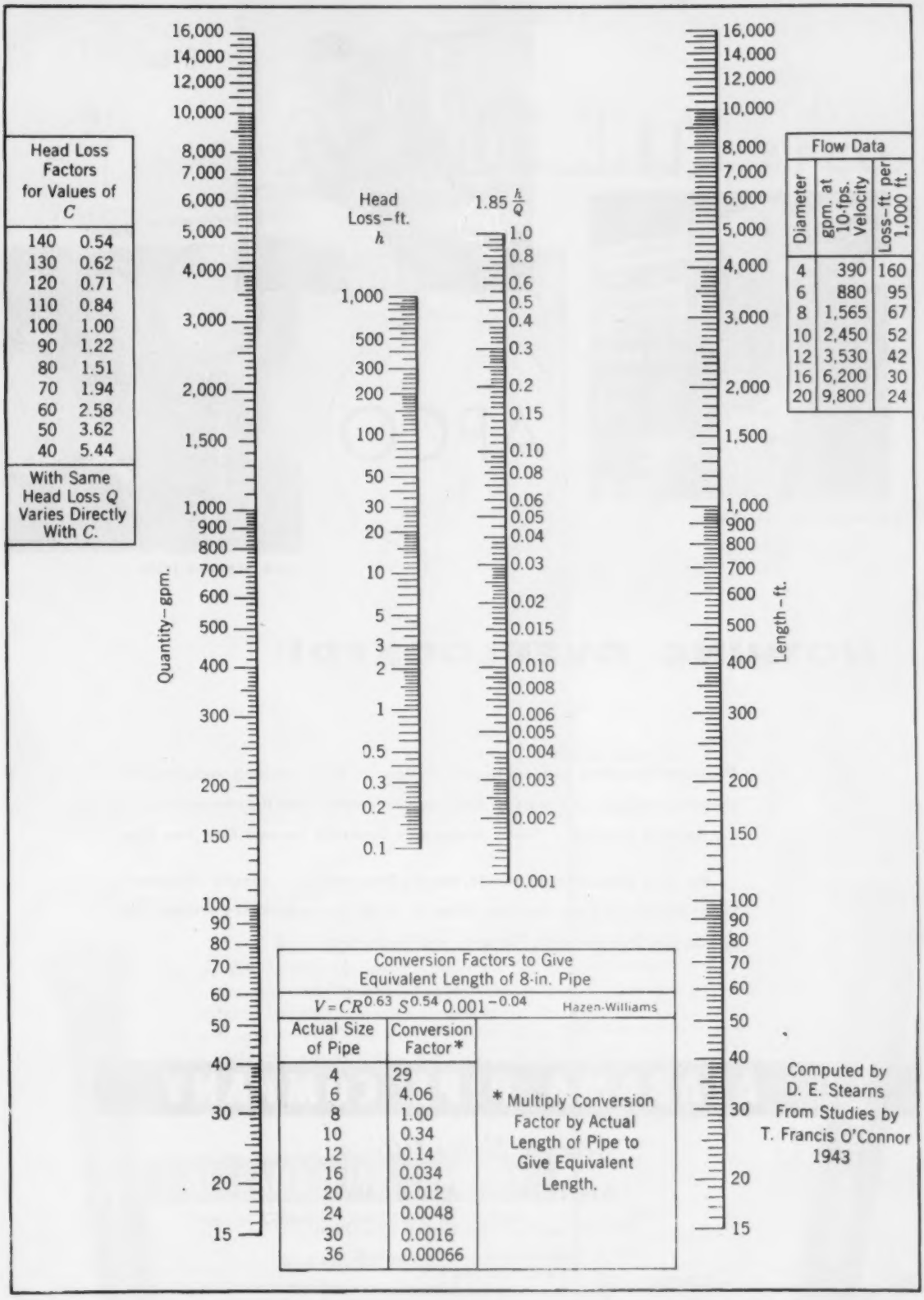

Fig. 3—NOMOGRAPH for flow analysis, based on Hardy Cross method
For pipe sizes 4 to 36-in.; head loss 0.1 to 1,000 ft.

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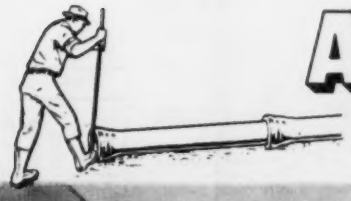
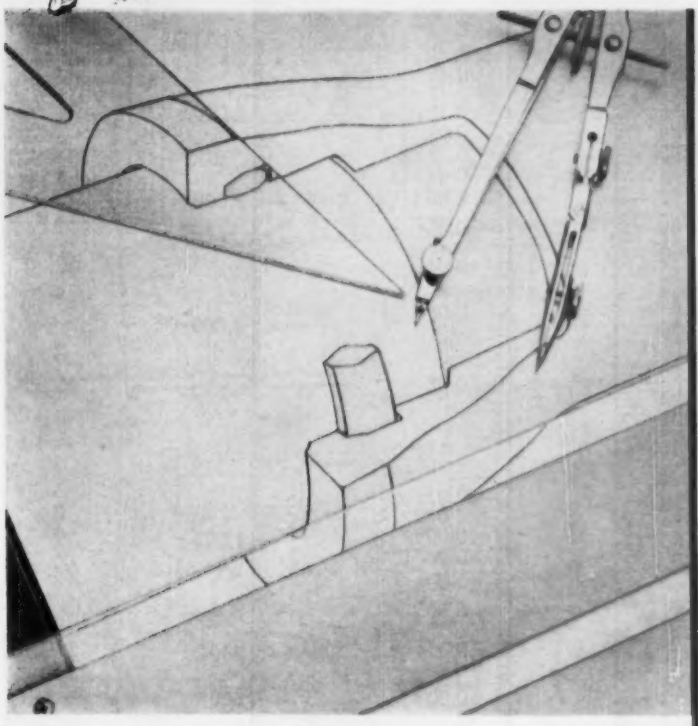


ALTITE JOINT® By APCO

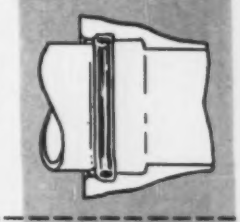


Four Operations
As Simple As Falling Off a Log—

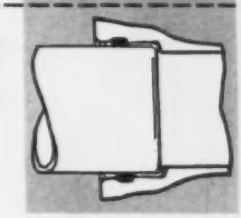
Insert Rubber gasket in bell end of pipe — you can't put it in wrong — A child can do it.

Wipe on a small amount of special lubricant—This reduces friction.

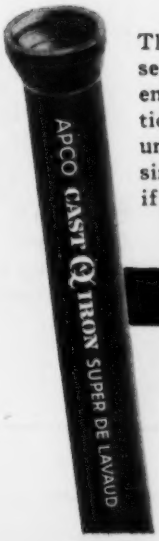
Insert plain beveled end of pipe — there are no grooves, ridges or tips on gasket to interfere with smooth insertion.



Small amount of pressure required to force plain end to bottom of socket—Your simple, time saving joint is completed.



Efficient, Economical and Fool Proof—



The **ALTITE JOINT®** has been subjected to a series of rigid tests much more severe than are encountered under the most extreme installation and service conditions in the field. Even under extreme conditions, this joint is so simple to install—you could hardly go wrong if you tried.

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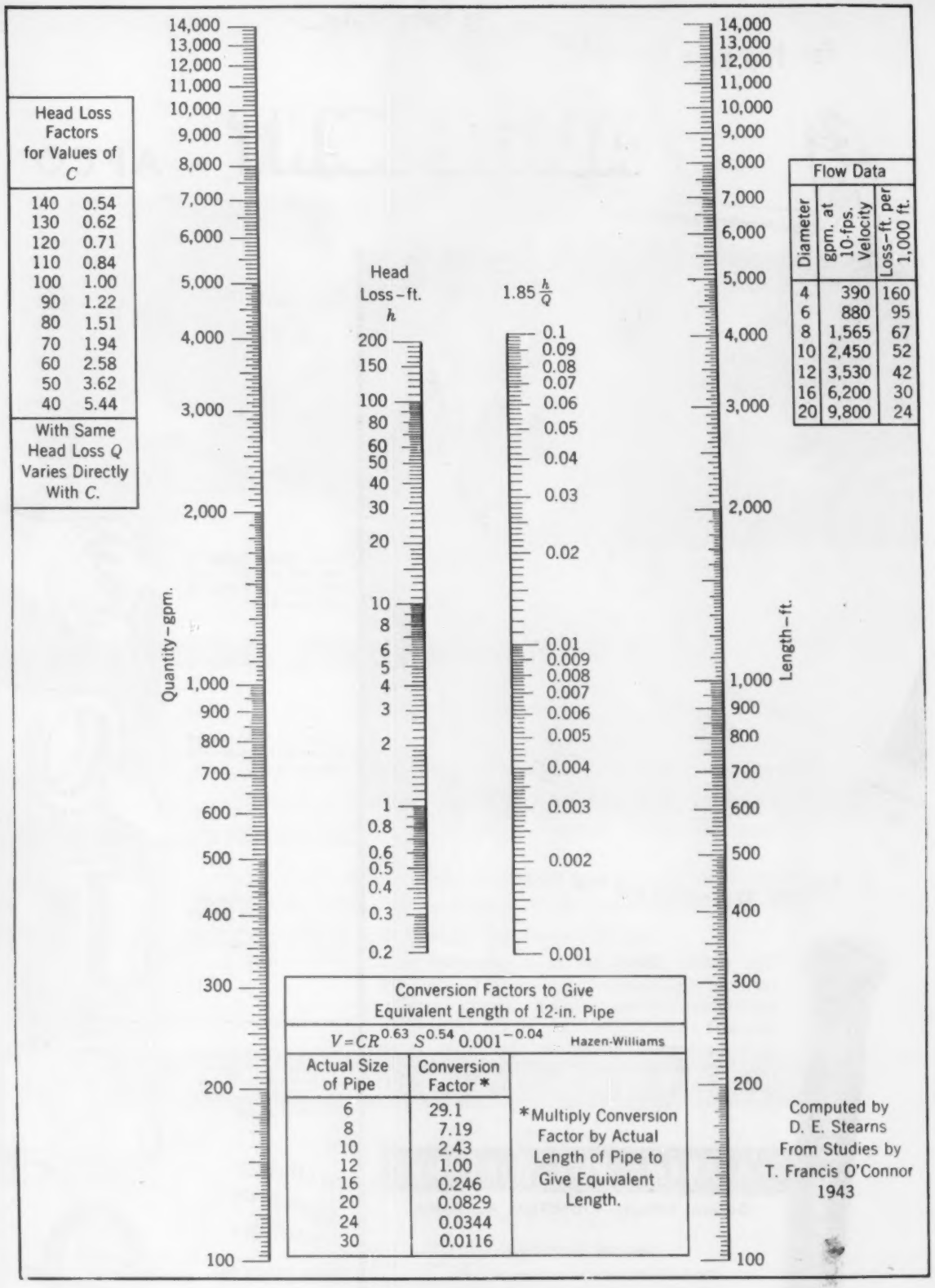
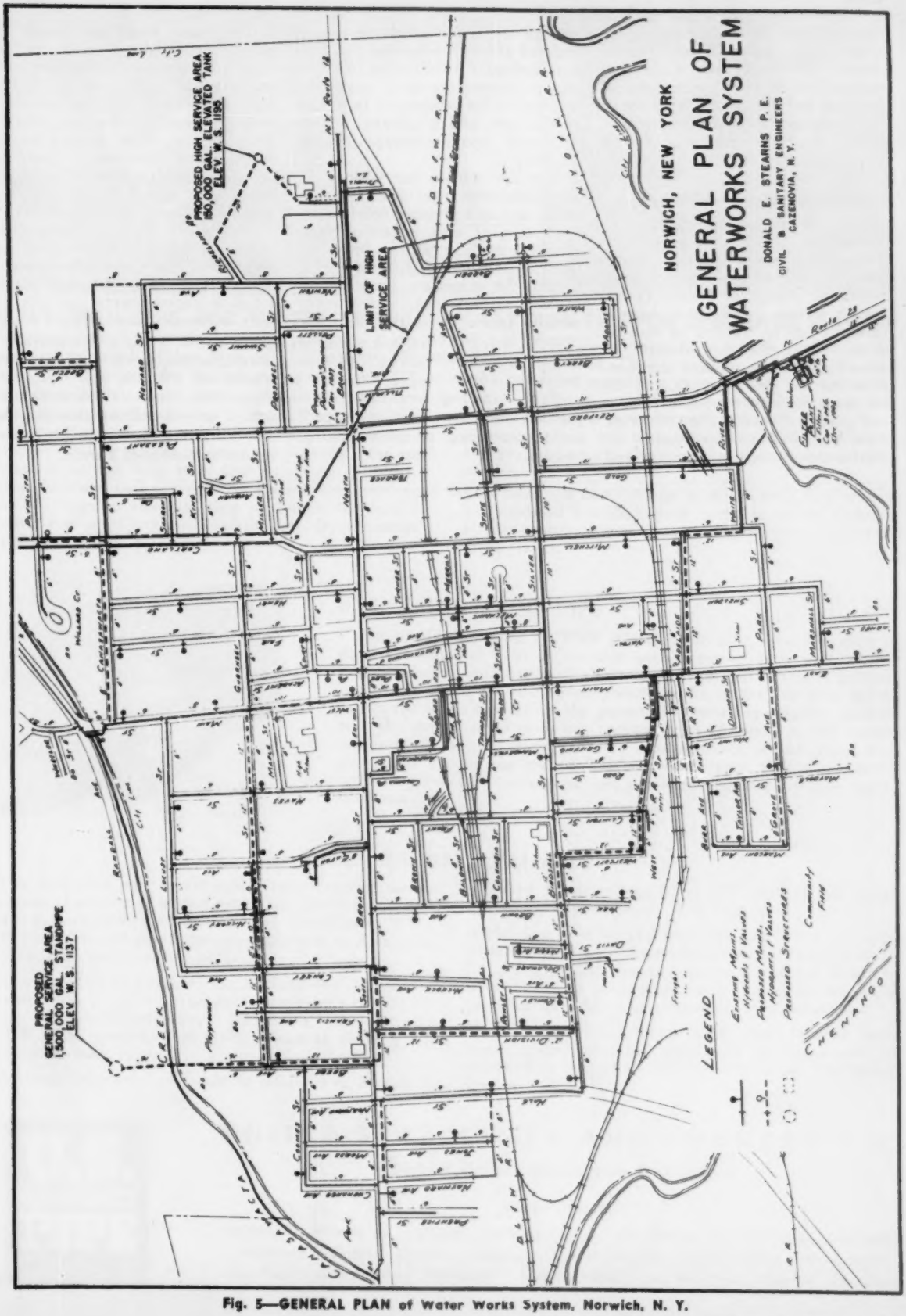


Fig. 4—Nomograph for flow analysis; based on Hardy Cross method
For pipe sizes 6 to 30-in.; head loss 0.2 to 200 ft.


NORWICH, NEW YORK
GENERAL PLAN OF WATERWORKS SYSTEM
DONALD E. STEARNS P.E.
CIVIL & SANITARY ENGINEERS
CAZENOVIA, N.Y.
PROPOSED HIGH SERVICE AREA 150,000 GAL. ELEVATED TANK ELEV. W.S. 1195
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LEGEND
Existing Mains, Hydrants & Valves
Proposed Mains, Hydrants & Valves
Proposed Structures
Community Park
CHENANGO
CREEK

Fig. 5—GENERAL PLAN of Water Works System, Norwich, N. Y.

determination. Since the feed into the system may come from several sources which include a pumping station, gravity feed, combination of pumping and gravity and from one or more storage tanks or reservoirs it is necessary to account for all of these in the hydraulic study.

Determining Improvements Needed

Once the true condition of the pipe network is known it is possible to determine various improvements needed. These may be new pipe lines, additional storage or booster pumping. It is now important to keep a careful check on the cost of new facilities versus the improvement obtained so that the desired improvement to the pipe network may be made for the least expenditure.

Figure 5, "General Plan-Norwich, New York Waterworks System" indicates the new mains, pumping and storage facilities which we recommended after a comprehensive field and hydraulic investigation. Our studies showed the most economical solution to the problem to be a high service area and a general service area with separate storage facilities for each.

It is our opinion that when a desired improvement is under consideration, such as a pressure deficiency in a particular area, a careful study should be made to outline a broad improvement program that may reach beyond the immediate needs of the problem to be solved. Such a study permits future constructions at the proper time to achieve a complete system rehabilitation. It attempts to avoid the common "Hit or Miss" method of adding new mains to a distribution system with little regard for proper sizing or most effective location.

Too many times new mains are constructed where they do not accomplish the job for which they were constructed because there was no factual study made to show ahead of time what such construction could accomplish. In other words it was hoped that desired result would be accomplished but there was uncertainty until an actual test after construction showed the final answer.

The writer has seen several instances of this kind of loose planning and knows that it is a quite common and costly process. Technical advice for such improvements generally effects economies that are far reaching and significant. The engineer's job is to seek to determine the most economical solution that will solve the problem. Such a solution may result in an expenditure that may be only a fraction of what might be expended without such a study.

A western city uses 12" TYTON JOINT for its water supply line.

Installing 14" TYTON JOINT pipe for a sewer force main in a southern city.

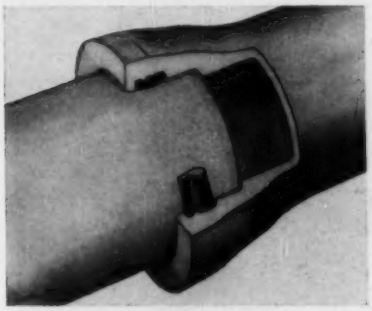
CAST IRON PIPE FOR WATER SERVICE

The practice of using cast iron pipe for water service started in Europe around 1455 and around 1820 in this country. This practice has continued down through the years and it is still the most widely used type of pipe for water distribution systems. The most desirable combination of strength and long life has made and still makes the use of cast iron pipe the most economical in the long run. Our strategically located foundries are well equipped to furnish cast iron pipe and fittings in sizes starting at 2-inch for intakes, pump stations, filtration plants, supply, feeder and distribution mains.

CAST IRON PIPE FOR SEWERAGE SERVICE

Cast iron pipe and fittings have a wide application in the sewerage field. They have three outstanding properties: 1. tight pressure type joints that prevent infiltration, 2. beam strength, compressive strength and bursting strength to withstand severe installation conditions, 3. long life and resultant low amortization charges that have been proven by years of satisfactory service.

Cast iron pipe and fittings in sizes 2-inch and up can be furnished for flow lines, pressure mains, siphons, stream crossings, outfalls, pumping stations and treatment plants.



U. S. TYTON JOINT PIPE

The newly developed TYTON JOINT® for U. S. cast iron pipe is simple, sturdy and tight. It has only one accessory—a circular rubber gasket which is modified bulb shape in cross section. TYTON JOINT is easily made up by placing the gasket in the socket and then lubricating the inside surface of the gasket. The entering spigot is pushed past the gasket until it makes contact with the base of the socket compressing the gasket between the outer surface of the spigot and the gasket seat of the socket. The result is a joint that will remain tight at pressures in excess of test pressures required by pipe specifications.

TYPES OF PIPE AVAILABLE

Our cast iron pipe centrifugally cast in metal molds is manufactured in accordance with American Standard Specifications A21.6 or Federal Specification WW-P-421a. Pit-cast pipe is made to conform to American Standard Specifications A21.2.

Fittings (bell-and-spigot) can be furnished in accordance with American Standard Specifications A21.10 for the short-body type 3-inch to 12-inch, also A.W.W.A. Specifications C100 3-inch to 60-inch for the long-body type.

Fittings (flanged) are made to conform to American Standard Specifications Class 125 (B16.1) and Class 250 (B16b) or long-body A.W.W.A. type.

Mechanical joint for cast iron pipe and fittings is made in accordance with American Standard Specifications A21.11. Pipe and fittings can be furnished with cement lining in accordance with American Standard Specifications A21.4 or manufacturer's standard.

Tyton Joint pipe, roll-on joint pipe, flexible joint pipe, flanged pipe and plain end pipe are made to standard or manufacturer's specifications, whichever are applicable.

U.S. cast iron PIPE

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"Slip-on" Joint Pipe

by FRANK C. AMSBARY

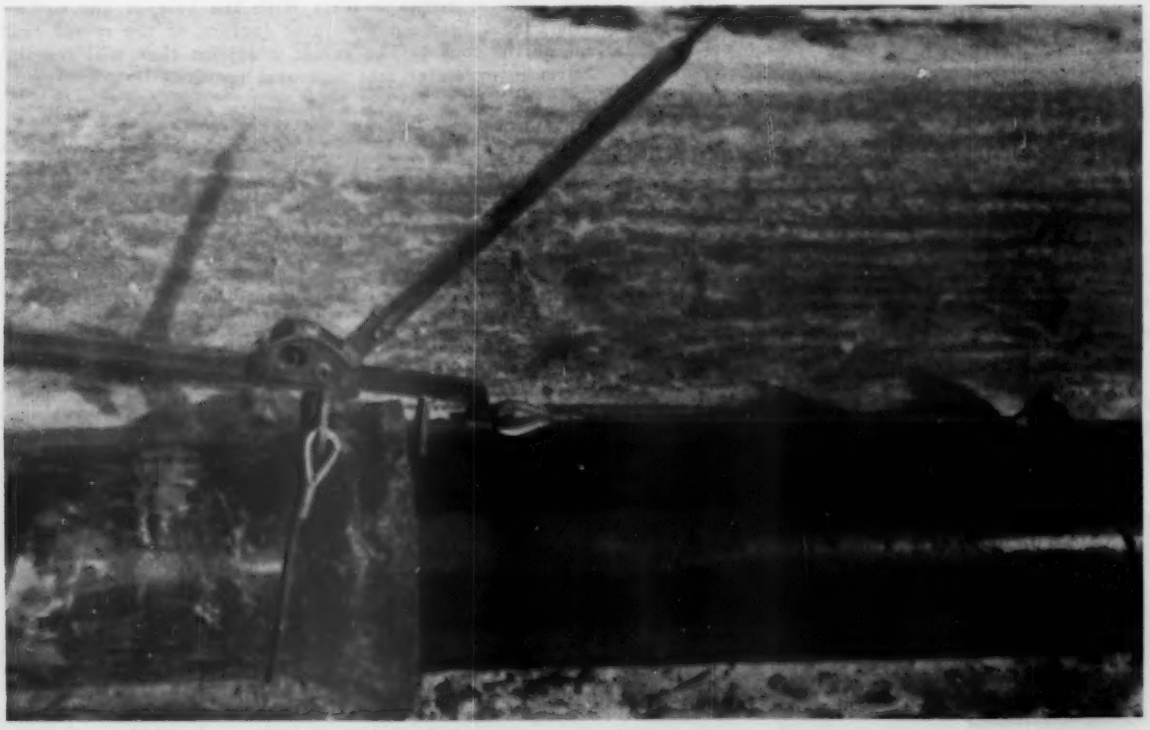
Vice President and General Manager, Long Island Water Co., Lynbrook, L. I., N. Y.

In an investigation made of the experience of four different utilities and from data from other sources on the installation of "Tyton" Pipe, it seems safe to say that this recently developed joint is the most significant advance so far made in cast iron pipe. Bell holes that are necessary with both bell and spigot and mechanical joint pipe are eliminated. Also in the case of bell and spigot pipe compared with the "Tyton" joint, the work force can be reduced by not less than two men and in addition the store's account is simplified by the reduced quantity of sulphur compound, or lead, and hemp or one of the hemp substitutes, with the resulting decrease in bookkeeping required and money tied up. In the case of mechanical joint pipe the inconvenience of follower rings and nuts and bolts is eliminated. When single-gasket joints are available in fittings and appurtenances, all other types of joints will become obsolete.

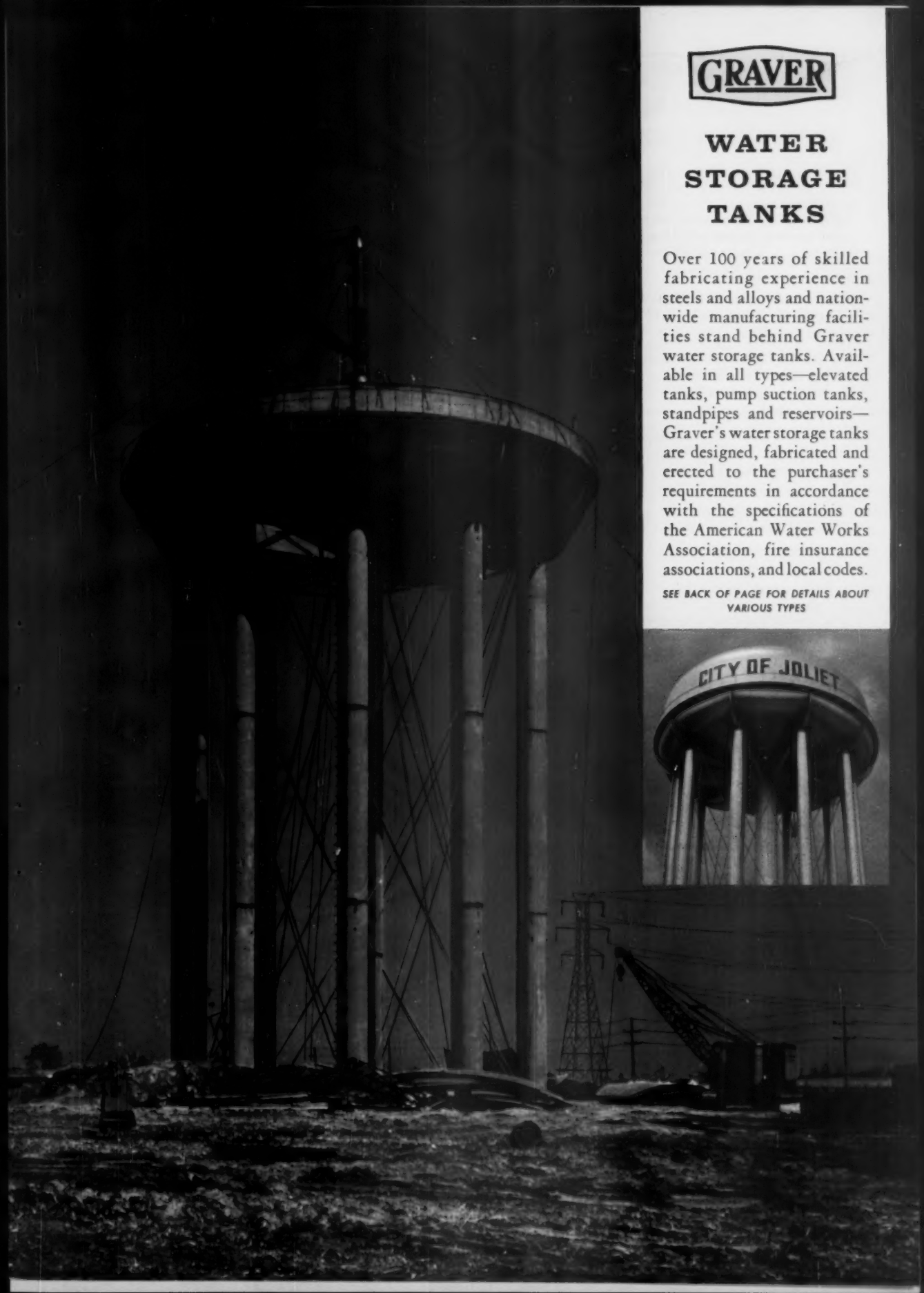
Long Island Water Corp.

Relative to the elimination of poured joints in the laying of "Tyton" joint it has been found at the Long Island Water Corp. that the presently manufactured AWWA ringtight 6 in. valve will slip over the spigot of the 6 in. "Tyton" pipe making a completely tight joint. In sizes over 6 in. the outside diameter of the pipe is too great to accommodate the ringtight joint of valves of comparable size.

The experience of the Long Island Water Corp. is too limited to furnish explicit data. This type of joint was only recently made available in that area. Enough experience has been had, however, that the contractor who installs all of the company's pipelines, while absorbing three pay increases in his pipe laying crews sees fit to continue to install extensions of less than 500 ft with no increase in cost per foot and extensions of 500 feet and over at a less cost per foot, which will more than offset the increase in cost of "Tyton" pipe over bell and spigot using sulphur compound. No diffi-



MAKING UP a 12 inch cast iron pipe with a jack.



GRAVER

WATER STORAGE TANKS

Over 100 years of skilled fabricating experience in steels and alloys and nation-wide manufacturing facilities stand behind Graver water storage tanks. Available in all types—elevated tanks, pump suction tanks, standpipes and reservoirs—Graver's water storage tanks are designed, fabricated and erected to the purchaser's requirements in accordance with the specifications of the American Water Works Association, fire insurance associations, and local codes.

SEE BACK OF PAGE FOR DETAILS ABOUT VARIOUS TYPES

GRAVER

ELEVATED WATER TANKS

Graver elevated water tanks are expertly fabricated from carbon steel, stainless steel or aluminum at Graver plants across the country and are erected on the site by experienced Graver crews to the highest welding standards.

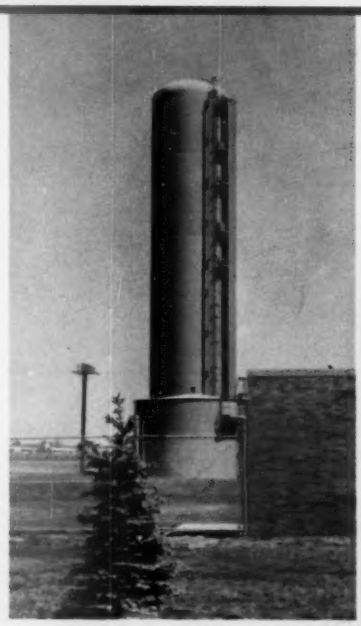
The selection of one of the standard sizes shown in the table offers the advantage of lowest cost and quick deliveries. Should one of the standard sizes not be suitable, special designs by Graver's engineers is a regular service.

Capacity Gallons	Diameter	Head Range	Number of Columns
25,000	18′-0″	13′-9″	4
30,000	18′-0″	16′-6″	4
40,000	20′-0″	17′-10″	4
50,000	22′-0″	19′-0″	4
60,000	24′-0″	19′-0″	4
75,000	26′-0″	21′-0″	4
100,000	28′-0″	23′-9″	4
125,000	30′-0″	25′-9″	4
150,000	32′-0″	27′-11″	4
200,000	36′-0″	29′-11″	5
250,000	40′-0″	29′-2″	6
300,000	44′-0″	30′-0″	6
400,000	50′-0″	30′-0″	8
500,000	55′-0″	30′-0″	8
750,000	65′-0″	35′-0″	8
1,000,000	86′-0″	25′-0″	12
1,500,000	104′-0″	25′-0″	12
2,000,000	112′-0″	30′-0″	16
2,500,000	122′-0″	30′-0″	16
3,000,000	124′-0″	35′-0″	20

GRAVER

STANDPIPES AND RESERVOIRS

Water supply storage tanks whose height exceeds the diameter are referred to as standpipes. When the diameter exceeds the height, they are called reservoirs. Standpipes normally provide static head to the water distribution system; reservoirs usually are intended for storage and reserve supplies. For both types of water tanks, there can be no standard sizes offered. Since the size and form depend upon local conditions and individual requirements, standpipes and reservoirs must be designed in accordance with the special needs of the users and the characteristics of the site.



GRAVER

PUMP SUCTION TANKS

Graver is an approved fabricator of pump suction tanks under the Factory Mutual Fire Insurance Companies specifications. All standard sizes shown in the table have ¼″ bottoms, 3/16″ self-supporting roofs and shells of thickness such that stress does not exceed 15,000 psi.

Rated Capacity Gallons	Actual Capacity Liquid Depth = Height—6″	Diameter	Height
100,000	100,470	27′ 0″	23′ 11½″
150,000	150,120	28′ 6″	31′ 11½″
200,000	200,730	33′ 0″	31′ 10½″
250,000	250,340	37′ 0″	31′ 7½″
300,000	300,550	42′ 0″	29′ 6″

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DIVISION—UNION TANK CAR COMPANY
EAST CHICAGO, INDIANA

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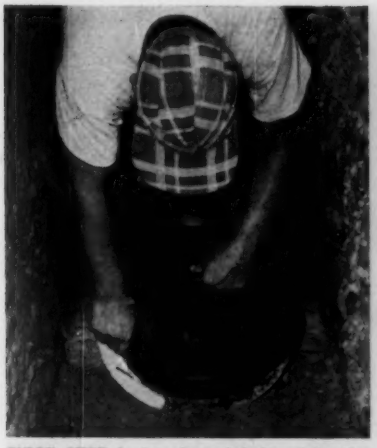

FIRST STEP is to place lubricant in the bell.

NEXT STEP is to insert the joint gasket.

culties of any nature have been experienced in the use of "Tyton" pipe at this plant. All sizes from 6 to 16 in. inclusive have been installed.

St. Louis County Water Co.

Frank E. Dolson, Supt. of Distribution, St. Louis County Water Co. reports that their use of "Tyton" pipe has been limited due to a labor situation. The labor union in effect refused to lay it. This problem has been worked out and due to their favorable experience, they expect to install "Tyton" pipe as standard practice.

The first job consisted of 3000 feet of 6-in. "Tyton" pipe in a new subdivision. Using the Company's standard procedure for installing 6-in. pipe, a standard crew consisting of six men installed 2200 feet of "Tyton" pipe in approximately six hours—.0163 man-hours per foot. The crew worked only at installing the pipe. Other personnel, consisting of a trenching machine operator and a trenching machine helper, together with a trenching machine, excavated the trench ahead of the crew laying the pipe.

Upon completion of the 2200 feet, the end of the pipe was capped and blocked and the entire strip subjected to a hydrostatic test. Water pressure was built up to 500 lb per sq in. by the use of a supplementary hand-type force pump and held at this figure for approximately one hour. An inspection of all joints on the pipeline indicated that the "Tyton" type of joint was able to withstand the test pressure with no visible leakage. There were two or three joints on the pipeline—for tees and fire hydrants, etc.—which were poured with sulphur compound and these joints, under the test pressure, showed some weeping.

This pipe was installed along a typical subdivision street that meandered considerably. Consequently it was necessary in installing the pipe, to make joints where considerable deflection was involved. It was observed that the "Tyton" type of pipe can be jointed together in a curved ditch under deflection conditions approximating about half of the maximum deflection allowable. It was also observed that there was no leakage from joints which were under maximum deflection.

The work of installing this type of pipe is considerably less than that required to install standard bell and spigot pipe with a poured joint. Yarning is entirely eliminated and, of course, the melting pot and pouring job is likewise eliminated.

This limited experience with the pipe indicated that, after proper lubrication was applied to the rubber ring, one pipe could be jointed to another pipe merely by pushing on the bell of the forward pipe with a light spade or crowbar pry. It is understood that very little more effort is required to join 8-in. pipes together but that in the 12-in. size and over it may be necessary to use the equivalent of a ratchet type of hoist or come-along.

Mr. Dolson believes that this type of joint is the best that it is possible to use. It is also his opinion that there will be material savings in its installations in almost every case. There are other cost contributing factors that will result in a net saving to the company. Some of these are increased productivity which will, of course, decrease all overhead and associated costs. Another plus will be that there should be a decrease in the maintenance expense of repairing joints on newly laid pipelines. Due to the flexibility of the pipe it is felt there will also be a decrease in the number of breaks on this type of pipe during the transition period between summer and winter ground temperatures.

Missouri Water Co.

L. J. Lukrofka, Supt. of Distribution at Independence, Missouri, has had considerable experience with the installation of "Tyton" pipe in sizes of 6 to 16 in. inclusive.

This company installed 13,500 feet of 12-in. "Tyton" pipe, whch was the first of this size to be made, and this installation was a real success. It was found on this larger size pipe that the most important factor in installing this pipe is to treat each section as a pendulum and take advantage of the weight of the pipe and by moving the pipe through an arc of about ¼-in. it can be sent home without the use of jacks, come-alongs, etc. This does require the pipe crew to develop a keen sense of rythmic coordination in the movement of this pipe. Once this coordination is attained, it can effect a 50 per cent reduction in installation man-hours. Team work pays dividends.

Mr. Lukrofka has found in the use of "Tyton" pipe, real and definite advantage in his pipeline construction.

1. *Stores Expenses*—Reduced overheads and less time required as it is necessary to stock only pipe and gaskets as compared to pipe, joint compounds, pouring snakes, pouring gates, pots, ladles, protective gloves, eye shields, joint compound heating furnances, jute, etc.

Less chance of operations being

A CROWBAR is the only tool needed to push the pipe home on sizes through 8 inch.

delayed, at any time, due to shortage or outage of any of the many items above.

Simplified records keeping and accounting in the stores department.

2. *Personnel Requirements*—Reduced basic pipe crew from six to four men by eliminating the kettleman and (mudder) joint pourer. On small jobs they find it most efficient to use a three-man crew and the power winch truck. Minimum of instruction and training required even when using unskilled labor.

3. *Installation Features*—a) *Deflection of Joints*—Joints can be safely deflected the maximum permissible provided the barrel of the pipe is not in contact with the bell.

Previously, in the use of sulphur compound joints, only minor deflections could be made, thus requiring use of many fittings or have many thin joints and future leaks.

b) *No Bell Holes*—It is not necessary to dig bell holes as required to install a pouring snake, or caulk a lead joint, or tighten bolts of a mechanical joint. This is a big saving factor.

c) *Minimum Re-checks Required*—Once the joint is put together and sent home there is nothing else to check, pick-up or remove. Mechanical joints must be re-checked or one joint in a big job is sure to leak because someone failed to tighten all bolts on that joint. No waiting for pouring gates to cool before removal.

d) *Minimum of Equipment on the Job*—Bucket of lubricant and crowbar are basic equipment required on the job, therefore, crews move right along and no concern for items lost or left behind.

e) *More Work Days*—Adverse weather, rain, mud, water, or other conditions that would have stopped a sulphur joint job have no effect on laying of "Tyton" pipe. It can be laid in almost any condition encountered thus gaining many more working days each year. This is highly important where rainy weather used to catch crews with a lot of ditch open, and sometimes it was days before they could get back into the job again.

f) *No Worry of Leaks*—This water utility has not had a single leak on a "Tyton" joint in over 70,000 feet laid to date. More freedom for foreman to cover entire job. Only thing he needs to know is that the joint is all the way home whereas constant checking is necessary on other type of joints.

PUSHING 16-in. pipe home with Gradall bucket at Long Island Water Corp.—12-in. pipe is made up in the same manner.

g) *Lines in Service Immediately*—As soon as a valve is installed in a section of line, that section can be placed into service and the jetting of the ditch or chlorination of the main can begin at once. This saves a great deal of "go back" time on these jobs. They have a large number of short jobs from 50 to 200 feet. Now they are able to make one of these short extensions, install the pipe, fill the line, jet the ditch, sterilize the line and clean up the job in a few hours time.

h) *Backfilling and Cleanup*—They are able to backfill the ditch immediately and keep within 50 feet of the pipe laying crew. This allows the job to be cleaned up fast, thus eliminating the hazard of open ditches, the expense of placing and tending barricades and flares, and the necessity of paying premium rates to have the ditch backfilled after the sulphur hardened and the pouring gates removed. Their public relations have had a tremendous upsurge because people are happy to see a job cleaned up so quickly.

Some Precautions

Mr. Lukrofka claims that in their experience there are no real known disadvantages in the practical installation of "Tyton" pipe, but does feel there are some precautions that must be carefully observed to assure optimum results. These precautions are:

a) *Gasket Groove in Bell*—This groove must be checked for any rocks or excess cement. Gasket will be difficult to seal if any of these are present.

b) *Blocking*—This really should be an advantage in that the pipe comes apart equally as easy as it goes together. This means that blocking must be provided for the full thrust that is to be developed on any bend, change of direction or end of line. They feel that they are getting better construction now because their crews have learned early that they cannot count on the joint to hold the pipe in place against pressure. Good construction methods demand blocking, however, regardless of the type of pipe joint used.

Gary-Hobart Water Corp.

Leo Louis, Vice Pres. & Gen. Mgr. at Gary, Ind., reports that during the past year they have laid over 100,000 feet of "Tyton" pipe ranging in size from 4 to 12 in. with sizes of 6 and 8 in. prevailing.

Their statistics for the year of 1957 are not complete and job conditions vary so that accurate comparison is impossible.

Mr. Louis says that at first one

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RHYTHMIC method, without use of jack, come-along, or crowbar, utilizes pendulum action of pipe suspended by cable from above.

might think that "Tyton" joint would result in a big savings. Labor of installation is less, but when this is analyzed, labor representing only approximately 25-30 per cent of the total cost, a 10 per cent savings in labor reflects about 3 per cent in over-all costs. On short jobs, 300 feet and less, while the job goes in quicker and easier, there is probably not any savings as the same crew would have laid the same amount of mechanical joint pipe. On jobs more than 300 feet long, savings will definitely be made.

The greatest savings occur with extensions of 1000 feet or more. Here pipe can be installed as fast as the ditcher will work. With a five-man crew they have laid over 1000 feet a day compared with an average of 350-400 feet using mechanical joint pipe.

Compared with mechanical joint pipe a real savings is made in the lower cost of "Tyton" pipe. The "Tyton" joint bell is stronger than the mechanical joint and, therefore, damage is reduced. Also stores handling is easier because there are no nuts, bolts and follower rings to store.

In summary, when the 1957 statistics are compiled, it is believed the cost will be about the same as 1956. But it must be remembered that labor rates have increased and at least that increase has been offset by installing "Tyton" pipe. Also the cost of valves and fittings has gone up but the lesser cost of installing "Tyton" pipe has also absorbed that increase. All in all, in a period of rising labor and material costs, by use of "Tyton" pipe Gary has been able to hold their own, cost-wise.

General Conclusion

Man-hours expended per foot for the installation of 6-in. "Tyton" pipe at the plants reporting for this article and at numerous other locations range from a low of .012 to a high of around .02. Comparable low man-hour figures apply throughout the larger sizes. It is believed that no other type of joint can equal these figures.

Plastic Pipe for Water Services

by JOHN P. DAWSON

Manager, Public Utilities Commission Dunnville, Ontario

The water works of the town of Dunnville, Ontario has had excellent results with the use of plastic pipe for water distribution services over the past six years.

Dunnville is a small town in southern Ontario about 40 miles northwest of Buffalo and about 200 miles northeast of Detroit. The town has a population of about 5000 with 2000 water services. The system was started for the purpose of furnishing water to locomotives on the railroad line. It was turned into a municipal water supply system in 1917.

Water Character is Unstable and Temperature Varies

The water is in a constantly changing condition because the source is a badly contaminated river. As a result this water is very hard on galvanized pipes and causes severe rusting in our cast iron water mains. The soil varies from quick sand, which is quite extensive, to a hard blue clay. Part of the area was a bog and part contains an old river bed complete with shells and beach sand. We feel that we have an area that will severely test any pipe put through it, and we think we have tried them all.

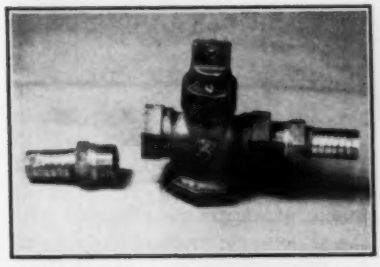
The water pressure is normally 42 pounds from an elevated tank, but during times when it is required by the fire department, the pressure is raised to 95 pounds.

There is another variable temperature, and we seem to have a complete range there, too. Two years ago, we pumped water at 29°F and last summer the water was 93°F at the pumps.

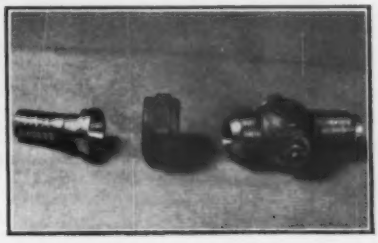
Plastic Pipe Tested

We agreed to test plastic pipe in 1950 on a new section of pipe that was to be a temporary arrangement to serve eleven houses. The chief idea was to save money since plastic pipe was less costly than copper. We nearly gave up the idea because the house owners concerned felt we were trying to push something over on them by putting in "hoses" instead of pipe for them. Every argument in the book was thrown at us. They claimed it made the water taste funny—not to be described clearly by them, just funny. They claimed the plastic pipe cut down the pressure too much, but the meters showed very clearly that 1-1/4-in. plastic pipe will carry enough water for 11 families without serious pressure drop. It was found that the drop at the end of the line was only 6-1/2 lbs in 900 ft. at any one time, on a Monday morning.

After the first experiment, we went further in our tests. These tests included an all winter test under a crushed rock laneway where the pipe was alternately frozen and thawed while traffic continued over it. The pipe, when dry in the Spring, was found to be unharmed.



EXPLODED view of curb stop using two adapters.



EXPLODED view of corporation cock.

SAMPLE connection from main to house service.
Plastic pipe with adapters and stainless steel clamps

Trouble with The Clamps

There is in service now about 5-1/2 miles of various sizes from 3/4 to 2 inch plastic pipe and so far, we have had no trouble with the pipe itself. There have been, however, many troubles with connectors and clamps.

We started operations with connections supplied at the same time as the pipe. They were easy to use and appeared to work fine, and we used the first twenty in one area. This was all that had been supplied to start with, and so we ordered more. Luck was with us, however, because the first of the twenty broke before we received the new shipment.

During the past six years, we have had to dig up every original hard plastic fitting that we buried. They were removed because they failed in service on two points. First, there was the matter of actual breakage. This was caused by traffic hitting the water boxes, often when a house was being built, and causing the box to jar the connection and break the hard plastic fittings into the curb boxes.

A more serious trouble, however, came from a basic failure. The hard plastic fittings absorb water and swell, and the pipe does not swell to the same extent. This swelling is a slow process that only shows up after a couple of years. The writer is not sure whether it occurs during the winter or the summer, because trouble has appeared at both seasons of the year. The strain caused by this swelling is very similiar to the strain caused by the freezing, and it has actually broken stainless steel clamps and split the pipe under the clamp. The hard plastic fittings is not broken, however, and when removed shows no real evidence of freezing.

Making Our Own Connections

This utility started making its own connections after the failure of the hard plastic fitting had threatened our use of plastic pipe. Our men were so satisfied that plastic pipe was better in all respects for our water system, that they themselves invented fittings that have proven to be reliable as well as easy to make. These fittings along with an improved method of clamping seems to have removed our troubles. We now use asbestos-cement mains in conjunction with the plastic pipe, and thus we have got away from any corrosion problems.

More Troubles

It might be said that we in Dunnville might be living in a fool's paradise when we considered that the troubles with the hard plastic fittings were our only ones. In the summer of 1956 the town decided to put in a permanent street for the original 11 houses serviced with the 1-1/4 in. plastic pipe. This involved digging up this 6 year old pipe and moving it, and the payoff came when the house owners, being approached by the town to pay for a permanent new water main, only one man agreed to sign a petition for another main because they all said they were satisfied with the present service.

The pipe was re-laid after washing it off and it looked like new. It had been buried in swamp and clay and quicksand. Even the white stripe and name were clearly legible on it. One galvanized iron service pipe was in need of replacement because it looked as though it would not take another six years without trouble. The strongest recommendation for plastic pipe came when the men who had originally opposed it six years before, came to our utility to buy enough to replace their own services with the plastic pipe.

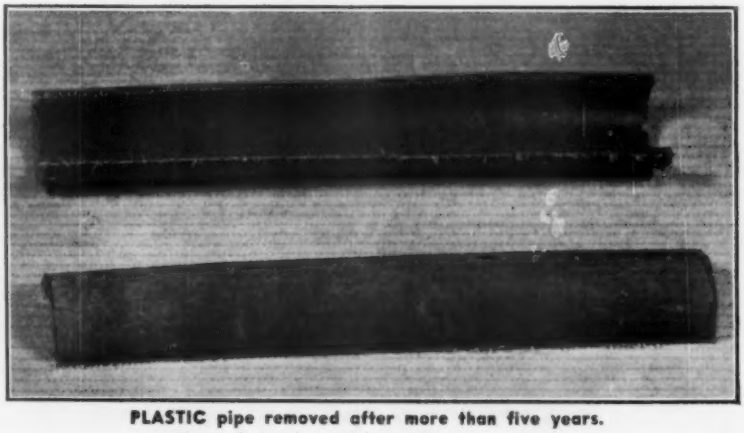
We have had two experiences with frozen pipe. One service was to a boat club that didn't matter, and the other was turned on before it had had enough cover over it, and it froze before being used. Neither pipe was damaged by freezing but we found no way to thaw them. The pipe is a non-conductor so it could not be heated with electricity. A hydrant thawing steam generator was tried as well as a heated wire but both these were only successful about 18 ft from our outlet so it was necessary to wait until Spring. The one service goes through old filled land, and had caused trouble before with copper pipe. It is now encased in sand, and we will know in the future whether the sand will help.

A Method of Laying Plastic Pipe

Our system of laying the pipe is fairly simple. Using a standard main tapping machine, we tap the main and insert a standard main stop for copper. The regular nut is used, and a six inch length of regular 3/4-in. copper pipe is flanged into the nut, and assembled into the main stop.

The plastic pipe is then warmed, usually in the water of the radiator of the trenching machine, and the warmed pipe is forced over the copper pipe on the main stop. Finally, a stainless steel strap is installed around the connection with a small hand banding machine called a "Bandit." This type of connection is used again at the curb stop so that everything is a standard design except for the pipe and banding material. Copper service tubing is no longer used except to make the six inch coupling.

GALVANIZED Tee and plastic pipe removed after six years.
The Tee was leaking



PLASTIC pipe removed after more than five years.
Piece of pipe shown with Tee above is cut open

We have found—

1—That copper colored plastic pipe has no advantage over black except that the public are presumably fooled into believing the pipe is copper.

2—Black pipe has a higher bursting strength than grey plastic pipe when the water is hot.

3—One inch plastic pipe carries more water than 1-1/4-in. copper and 1-1/2-in. galvanized at 42 lb pressure.

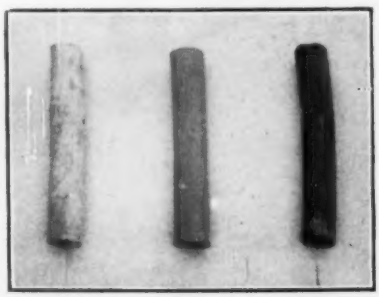
4—After six years, the carrying capacity of plastic pipe is *not* lowered even with an active type of water.

5—Plastic pipe has not failed in service during the six years we have used it. We are now using Carlon pipe with a green stripe to secure an even longer life expectancy.

6—The cost in service is less than one-half the cost of copper pipe of the same physical size.

7—If the plastic pipe freezes in service during the winter, there is nothing to be done but wait for it to thaw out.

If anyone finds a way to thaw out plastic pipe we shall be happly to hear from them.



PLASTIC pipe buried 5½ years compared to new pipe.
Left—Pipe as it came from the ground; Center—pipe after washing; Right—New piece of pipe.

Finding Sites for Elevated Tanks*

by CLYDE E. WILLIAMS

Pres. Clyde E. Williams & Assoc., Inc., South Bend, Ind.

The selection of a site for a proposed elevated water storage tank is important. This phase of planning usually comes after the determination of the volume and type of storage (whether ground or elevated), although it may in some cases have to be taken into consideration initially.

Once it has been established that an elevated tank is to be built, and the amount of storage has been determined, the selection of the general location, and, finally, the actual site or sites, is dependent upon these basic considerations: [1] how the deficiencies in the distribution system can best be reduced by the tank; [2] how the tank will affect the neighborhood in which it is to be located and how it will be received; and [3] how it will affect the water improvement project on a cost basis. These considerations are listed in their order of importance from the engineering standpoint, but, of course, either the problem of public acceptance or limited funds could be more pressing.

After proper consideration has been given to each of these questions, the possible sites for the elevated tank will usually be reduced to two or three.

In order to elaborate further on the problems in locating the elevated tank, the basic considerations will be placed into three categories: [1] engineering; [2] public relations; and [3] economics.

Engineering Considerations

The prime engineering concern should be the improvement of service, pressures, and fire protection for the community as a whole. If possible, improvements should be in the area most deficient in these necessary requirements of a water system.

A great many design engineers and water utility men believe that a storage tank should be located so that the high volume use lies between the pumping station and the storage. This system has many advantages and is particularly practical in smaller communities. It has the advantage that the center of the system (usually the area with the highest peak demands) can be fed from both directions during peak demands or fire demands. It often means that smaller feeder mains can be used or that the existing mains can be utilized to their fullest. This has the added effect of greatly increasing the volume of water that can be delivered to the high-demand area.

It is occasionally advantageous to place the elevated tank at or near the pumping station or treatment plant. This is true if the deficiencies in the system would not be improved by placing the tank out on the system and if the primary purpose of the tank is additional storage.

The location of the tank near the pumping station usually reduces the pumping head and, consequently, the power costs. In existing systems it sometimes permits the use of pumps, motors, and piping that might otherwise have to be replaced by higher-head and higher-capacity equipment.

Under certain conditions it may be advantageous to erect the tank near the filtration plant so that elevated storage can provide the backwash volume and pressure needed to eliminate the necessity for a backwash pump. In some smaller communities, aeration of the water in the elevated tank may also be considered as a part of water treatment.

Some engineers choose the highest elevation in the distribution system for the location of the elevated tank. In some systems where terrain and the existing water mains permit the location at the highest point, it is, of course, expedient to do so. It may be more prudent to add to the height of the tank (at, say, $500 for every foot) than to install large feeder or arterial mains over long distances at approximately $10 per foot. It should be pointed out that one of the functions of an elevated tank is to maintain adequate, uniform pressure. When a tank is placed on much higher ground than the rest of the system, care must be taken that none of the lower elevation areas have excessive pressures.

Once the general location of the elevated tank has been determined, selection of the specific site must be based upon several additional engineering requirements. It must be of adequate size to facilitate the construction and the storage of materials during erection of the tower. The site must be on well drained land, and located on soil that has suitable bearing values to support the structure. It has become the practice to make soil borings and have bearing tests made before the actual site is recommended for construction. Provision should also be made for handling overflow and waste drainage.

The tank must be placed on a site where it will not be a hazard to aircraft along civil airways. Civil Aeronautics Administration regulations specify that any structure 150 feet high or higher along, or within 20 miles of, a civil airway, must be approved for construction by CAA. Most elevated tanks do not reach 150 feet above ground level, but it is a good practice to check with CAA before finally deciding on a particular site.

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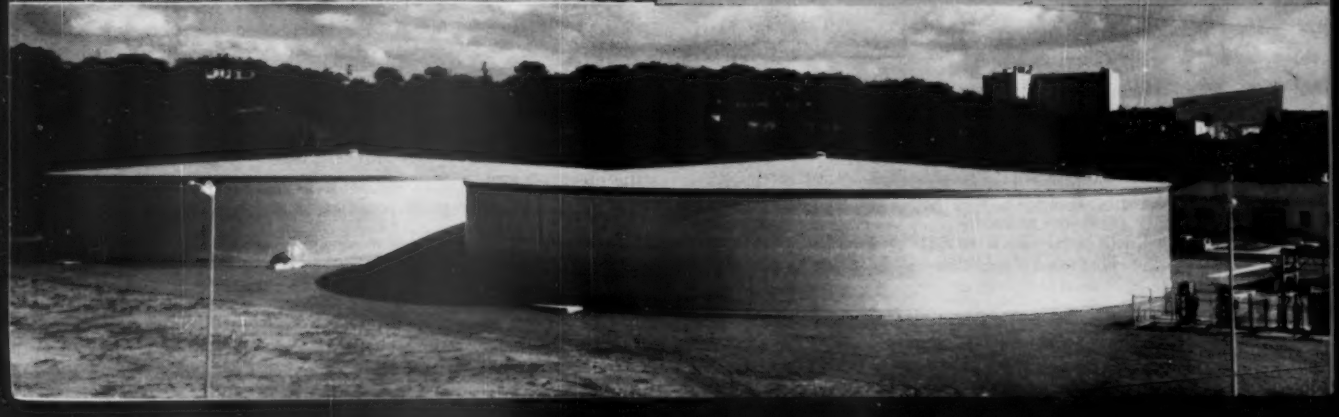
WRITE *your* nearest CB&I office for literature on any of the tank designs shown here.

Left: RADIAL-CONE tanks can be furnished with or without balconies. They provide pleasing symmetry, smooth lines and are easy to maintain. They are available in capacities to 3,000,000 gallons.

Below: CB&I RESERVOIRS can be provided in any capacity. These are 200 ft. in dia. and serve Fort Worth, Texas with more than 12,000,000 gallons of storage. Many roof types are available including: cone, ellipsoidal, umbrella, dome, and others.



COORDINATED DESIGN, engineering, fabrication and erection services can provide structures to suit specific aesthetic requirements. This 2,000,000-gal. ornamental reservoir is one of four CB&I structures which are now serving Atlanta, Georgia.

SPHEROIDAL elevated tank at Cincinnati, Ohio is 68-ft. to bottom, has capacity of 2,500,000 gallons. This type of structure can be furnished with large, smooth or fluted central riser, or with two circles of columns.

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Capacity in U.S. Gals.	Diam. of Tank	Range in Head
40,000	20′ 0″	18′ 0″
50,000	22′ 0″	19′ 0″
60,000	24′ 0″	19′ 0″
75,000	26′ 0″	21′ 0″
100,000	28′ 0″	24′ 0″
125,000	30′ 0″	25′ 6″
150,000	32′ 0″	27′ 6″
200,000	36′ 0″	29′ 6″
250,000	40′ 0″	29′ 0″
300,000	43′ 0″	30′ 0″
400,000	46′ 0″	35′ 0″
500,000	50′ 0″	37′ 6″
500,000	56′ 0″	30′ 0″

TORUS-BOTTOM ELEVATED TANKS

Capacity in U.S. Gals.	Diam. of Tank	Range in Head
200,000	36′ 0″	28′ 6″
250,000	40′ 0″	29′ 0″
300,000	43′ 0″	30′ 0″
400,000	46′ 0″	34′ 9″
500,000	50′ 0″	36′ 10″
500,000	56′ 0″	30′ 0″

RADIAL-CONE BOTTOM ELEVATED TANKS

Capacity in U.S. Gals.	Diam. of Tank	Range in Head
500,000	60′ 4″	25′
750,000	74′ 3″	25′
1,000,000	86′ 0″	25′
1,000,000	78′ 0″	30′
1,000,000	71′ 6″	35′
1,500,000	96′ 0″	30′
1,500,000	88′ 0″	35′
2,000,000	102′ 0″	35′
2,500,000	114′ 0″	35′
3,000,000	126′ 0″	35′
3,000,000	117′ 0″	40′

SPHEROIDAL ELEVATED TANKS

Capacity in U.S. Gals.	Diam. of Tank	Range in Head
500,000	62′ 6″	25′
750,000	75′ 6″	25′
1,000,000	87′ 6″	25′
1,000,000	80′ 6″	30′
1,000,000	76′ 0″	35′
1,500,000	98′ 0″	30′
1,500,000	92′ 0″	35′
2,000,000	105′ 0″	35′
2,500,000	116′ 6″	35′
3,000,000	129′ 0″	35′
3,000,000	120′ 0″	40′

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Detroit 26 ..... Lafayette Bldg.
Houston 2 ..... C&I Life Bldg.
Kansas City, Mo. ..... 7928 State Line Rd.
New Orleans 19 ..... Pan American Life Bldg.
New York 6 ..... 165 Broadway
Philadelphia 2 ..... 6 Penn Center Plaza
Pittsburgh 19 ..... Porter Bldg.
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NEW SPHEROIDAL tank (*below*) and TORUS BOTTOM tanks are recent CB&I designs. Both provide large diameter and shallow tank depth to provide for reduced pressure variation.

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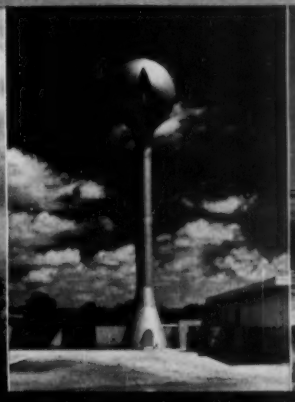


Chicago Bridge & Iron Company

Public Relations

The next considerations in the choice of the tank site are its effect on the surrounding area and the winning of neighborhood acceptance. After having given careful study to the problem of choosing a location from an engineering standpoint, one dare not neglect the public relations aspects. A slogan adopted by the Engineers Joint Council regarding public relations is "good performance" publicly appreciated, because adequately communicated." The perfect engineer design would be inadequate if not publicly appreciated because it had not been fully explained and discussed.

In the author's experience, by far the larger percentage of elevated tanks for small communities are constructed in desidential areas, because it is in these areas that problems of supply, small mains, and area growth are most common. These are the major problems of the local government officials and the water works departments.

Water storage structures do not necessarily devalue property, and once in place they are regarded as indispensable necessities. Residential home areas are developed around them without further worry about their location.

In recent years tank companies have improved the design and appearance of tanks. With the new ellipsoidal and spherical designs and the tubular columns, elevated tanks are no longer objectionable in appearance. The tank, if it is well designed, should have a prominence which is a constant reminder of its valuable service to the community.

An elevated storage tank may also be a landmark for a community. The traveler can be informed miles ahead of the name of the community he is approaching, if the name is painted in large black letters on an attractively painted white or pastel tank. Therefore, when picking the site for a tank, some consideration may be given to its prominence as an advertising meduim for the community.

There are many tanks located in residential or semi-residential areas. It should not be necessary to change a site simply because the citizens object to having a tank at the old site. The engineer, of course, should attempt to prepare officials for possible objections by showing pictures of beautifully painted, pleasing tanks in other communities, or by asking them to talk to residents in the areas where such tanks are located. Such an approach should succeed in overcoming any objections.

Some citizens object to the location of an elevated tank in a residential area owing to the possible danger of its falling during a tornado or storm. This objection can be countered by pointing out that after the tornado in suburban Kansas City, Mo., in 1957, the only structure remaining erect and undamaged was the elevated storage tank, which was designed to withstand the onslaught of wind and weather.

Another thing that the engineer and community officials should consider is the possible benefit to local industries. By erecting an elevated tank near industry, storage and pressure can be provided for both domestic and industrial use. There are many examples of industries that have been able to install sprinkler systems, thereby reducing their insurance rates, by a cooperative effort in the placing of a tank.

By using trees and shrubbery, the elevated tank columns and piers can be easily camouflaged at eye level. This may reduce many of the objections of people whose homes are adjacent to the tank.

A 250,000-gal double ellipsoidal tank at Buchanan, Mich., painted white, was built on high ground in part of the city where the pressure and supply were low. With the tank at this site, the area of high-volume use is between the well pumps and the storage. The site is in a residential neighborhood opposite a new grade school. No objections were raised by citizens in the area except by one person who had a high radio antenna and claimed that the tank would affect his reception.

Highland Ind. has a 500,000-gal tank painted sage green. It is on high ground and has only a 60-ft tower. This tank is also an advertisement for the town, being located on a much-traveled east-west highway. Trees cover the legs of the tank from the nearby homes and the residents seldom realize that it is there.

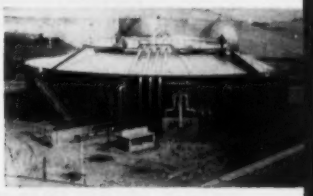
A 200,000-gal capacity spherical tank, painted light green, is located just a few miles down the highway from the Highland tank. It is in a low-pressure commercial area and provides good advertising for Griffith.

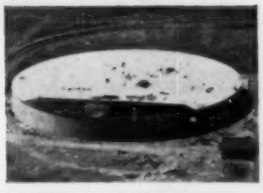
Economic Considerations

The last consideration in the choice of a tank site is how the cost of the overall project will be affected by the selection. Two of the significant factors are: [1] the cost of the feeder mains to get the water to and from the tank; and [2] the cost of the site. Many times odd-shaped parcels of land, or areas which do not particularly lend themselves to building construction, can be purchased at a reduced cost. Sometimes industries will donate the land for the consideration of having the tank located near them.

Conclusion

The location and the choice of the elevated storage tank site must be unanimously agreed upon by all concerned—the engineer, the community officials, the board of health, the fiire underwriters, the local industries, and the individual citizens. It should always be kept in mind that the location selected shoulld meet community needs, provide dependable service, and have public approval.





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PRELOAD PRESTRESSED CONCRETE TANKS

- *Water tanks*
- *Standpipes*
- *Elevated tanks*
- *Digestion tanks*
- *Pressure vessels*

Prestressed concrete offers the following advantages:

- Economical first cost
- Maintenance costs 75% less than other types
- Architecturally pleasing
- 75% contract price is spent in the local community
- Standard, proven design

Send today for more information on these

MODERN PRESTRESSED CONCRETE TANKS

PRELOAD

THE PRELOAD COMPANY, INC.

211 East 37th Street, New York 16, New York

ENGINEERS IN PRESTRESSED DESIGN

history of prestressed tanks

The history, development, use and acceptance of prestressed concrete tanks justify their consideration for any storage project.

Preload started designing and constructing prestressed concrete tanks in the mid 1930's. An early example of this work is the 50′ diameter x 100′ high 1.5 MG standpipe constructed for the City of New Britain. Constructed in 1936, it has required no maintenance and is still in constant service. In 1943, Preload introduced its wire winding methods which have been in successful use throughout the world ever since. This mechanical method of prestressing tanks is the only U. S. method of prestressing, including linear methods, which has been exported for extensive use in foreign countries under license agreements. Operations have been or are under way in Algeria, Australia, Canada, Cuba, Colombia, France, Great Britain, Italy, New Zealand, Peru, Union of South Africa, Uruguay and others.

Through 1947, some 470 tanks had been constructed to Preload designs totaling 166,000,000 gallons. This averages 350,000 gallons per tank. Since 1947 and through 1957, over 660 tanks have been constructed to Preload designs; these total one billion gallons and average 1,500,000 gallons per tank. This sharp rise and increase in use in the past decade strongly indicates the widespread acceptance of this method of construction. These tanks have been built for ground and elevated water storage, water treatment, sewage digesters, petroleum storage and many other industrial applications.

In recent years, the use of prestressed concrete for larger and larger tanks has become evident. Last year saw the completion of 2—292′ diameter 13,000,000 gallon tanks for the City of Reading, Pa. Gilbert Associates Inc. were Consulting Engineers. 1958 will see the City of Springfield, Mass. advertise for bids for 2—15,000,000 gallon tanks, 320′ in diameter for addition to their Provin Mountain Reservoir. Bogert & Childs Associates are the overall consultants. The East Bay Municipal Utility District of Oakland, California, is now constructing a 10 MG tank. This Utility has nearly 40 prestressed concrete tanks in service.

In brief, Preload tanks are not something new, prestressing is not a fad, it's a tool to be used by the resourceful designer to help his client solve a storage problem.

what is a prestressed tank

A concrete tank is considered to be prestressed when it is designed and constructed so that when the tank is full, the ring forces created do not cause any circumferential tensile stress in the concrete. Since a prestressed concrete tank is designed as a cylindrical shell with edge restraint, vertical moments result when the tank is initially prestressed and moments of opposite sign but of less magnitude result when the tank is filled. These moments and the resulting tensile stresses and how they are reinforced for are probably the most important aspect of prestressed concrete tank design. A tank wall may be reinforced vertically by prestressed or mild steel reinforcement or a combination of both depending on the magnitude of the residual tensile stress. In any case of residual tension, mild steel reinforcement must be provided.

In a Preload type prestressed concrete tank, the uniformly stressed circumferential prestressing is so designed and placed that no circumferential tensile stresses are created when the tank is full. The Preload tank also provides a well balanced design for the vertical moments due to edge restraint, temperature differentials, backfill, etc., so that total bending tensile stresses are low.

In the above description of a prestressed concrete tank, you will note a strong emphasis on the matter of vertical bending stresses. We accept as axiomatic that no circumferential tension can occur in a wire wound Preload tank; therefore, the major emphasis in design is found in the problem of vertical bending.

Our current practice in designing tanks including full design criteria is described in detail in our Bulletin T-19, "Design of Preload Tanks," which is available on request. These criteria are accepted by agencies of the Federal Government, the Portland Cement Association and many municipalities.

Since 1953, Preload has been using a rubber pad at the base of the wall and under the dome ring of dome roofed tanks in order to reduce the edge restraint as much as possible. This feature has made possible very great improvement in Preload tanks. Dumbbell type rubber water stops are used between the footing and wall and in all floor and wall construction joints so that positive joint tightness is assured. With the rubber pad, on which the wall floats, the restraint is accurately determined from shear resistance data of the rubber furnished by the manufacturer. Vertical bending due to edge restraint is reduced to about 30% of that resulting from even the best of sliding joint preparations abandoned by Preload because of the uncertainty of field results. Owners should note carefully any proposed designs based on sliding base details as nearly 50% of the circumferential prestressing usually must be applied before static friction is overcome and sliding starts. Until sliding does start, the base must be considered as hinged and the vertical stresses analyzed accordingly. The rubber pad base joint contains patented features.

An example of the effect of edge restraint on the vertical stresses is shown in the table on the following page taken from Preload Bulletin T-19.

construction

The construction of the floor, core walls, and roofs of Preload tanks follows sound standard construction practice, and may be of concrete or pneumatically applied mortar depending on the size of the tank.

floors

Floors for Preload tanks may be of either 4″ poured concrete or 2″ pneumatic mortar. In each case ½% of reinforcement, each way, is provided. Pneumatic mortar floors normally do not have expansion joints. Poured concrete floors are usually subdivided for ease of pouring, but each construction expansion joint is sealed with a rubber water stop. For best results, floors should be kept moist or flooded with a thin layer of water until the tank is placed in service.

Preload heavy duty Merry-Go-Round wire winder, stressing .192 wire to 150,000 PSI initial stress. Two 13.0 MG reservoirs—292′ ID x 27′4″ SWD, Reading, Pennsylvania

	RUBBER PAD BASE		SLIDING BASE COEF. OF FRICTION—.5	
TANK EMPTY	OUTSIDE FACE	INSIDE FACE	OUTSIDE FACE	INSIDE FACE
Dead Load	+ 61	+ 61	+ 61	+ 61
Base Restraint	+175	—175	+445	—445
Summation	+236	—114	+506	—384
Temperature	— 70	— 70	— 70	— 70
Summation	+166	—184*	+436	—454*
TANK FULL				
Dead Load	+ 61	+ 61	+ 61	+ 61
Base Restraint	+ 29	— 29	—335	+335
Summation	+ 90	+ 32	—274	+396
Temperature	—169	—169	—169	—169
Summation	— 79	—137	—443	+227

* For the same stresses for both designs provide (454 — 184) = 270 psi with vertical prestressing (32,500 #/ft. of wall).

3 MG . . . 133' ID x 29' SWD water tank, Montgomery County (Dayton) Ohio

walls

The walls for Preload tanks may be built of either concrete or pneumatic mortar. It is usually economical to use pneumatic mortar when the walls are less than 6 inches thick; concrete when they are thicker. In each case, the forms are designed and erected in accordance with standard construction practice. Cast-in-place concrete walls are usually constructed in segments of full height. Rubber water stops are used in all vertical joints. After the walls have been shot or poured, they are allowed to cure and reach a strength of at least 1.8 times the initial circumferential compressive stress before the circumferential prestressing is applied. Vertical reinforcement as required by the design may be prestressed or standard mild steel bars, or a combination of both. The prestressed reinforcement usually is comprised of high strength bars or wire cables similar to those used for prestressing bridge girders.

roof

Roof design for Preload concrete tanks may be dome, cast-in-place flat slab, precast flat slab or cable suspended; the choice being dependent upon the basic tank design or operating requirements.

The recommendations of the Joint Committees of Standard Specifications ACI-ASCE for Concrete, Reinforced Concrete and Pneumatic Mortar, form the basis of Preload construction specifications, practice and recommendations. Detailed Technical Specifications for the construction of Preload tanks are available on request.

the prestressing operation

A circular tank is prestressed by winding high strength wire around the concrete core wall with a self propelled machine riding on and around the wall of the tank. The wire is stressed by drawing it through a die of smaller diameter than the normal wire. This operation is similar to the wire drawing process used in the mills for making the wire. Accurate stress levels are obtained and the stress around the tank is uniform because there is no slippage of the wire on the tank wall after it is in place in its stressed condition. A stress measuring instrument is available on each job to check the wire stress on the tank.

After the circumferential reinforcement has been placed, a coating of pneumatic mortar is applied to the outside wall to bond the wire to the wall and provide permanent protection against corrosion. For complete protection, the exterior coat of pneumatic mortar need be no more than 5/8" thick. When the design of the tank calls for multiple layers of wire, each under layer is given a 1/8" protective coating. The pneumatic mortar also lends a highly attractive appearance to the finished structure and requires no maintenance.

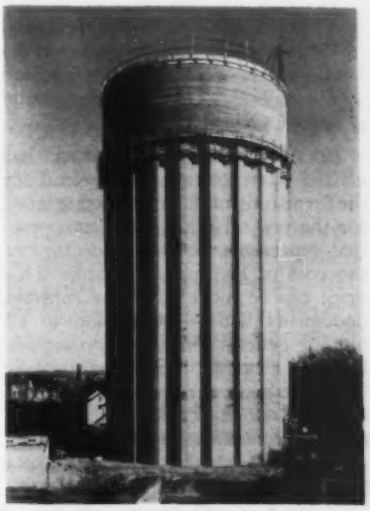
Preload, its construction licensees or competent local general contractors, experienced in reinforced concrete work, can successfully and economically build Preload tanks. Where local general contractors are to perform the general concrete work, Preload or one of its licensees will serve as a sub-contractor for the specialized portions of the work. We have intentionally "designed out" troublesome construction details and simplified construction requirements. To assist the local consultant, or inspection group of the owner, Preload has an "Inspection Check List" which provides helpful hints. It is also an inspection guide to assist the contractor, by proper inspection, in meeting the intent of the plans and specifications. Preload can furnish a Field Engineer for special inspection duties if desired.

design and cost estimating

The Consulting Engineer or Owner normally determines the medium of design and construction for a structure. With tanks the choice is between steel, reinforced concrete and prestressed concrete. Advantages and disadvantages can be stated for each. Seldom does an Engineer design a reinforced concrete tank and also a steel tank for taking competitive bids on the same job. It is just as inconsistent to place prestressed concrete in competition with either reinforced concrete or steel. The three types are not comparable in life expectancy, fire resistance, serviceability, maintenance, availability, or initial cost.

The Engineer can easily make a reasonably accurate cost estimate for a reinforced concrete tank. Steel companies gladly give prices for steel tanks to which must be added cost of foundations, painting, and such corrosion control methods as cathodic protection or interior coatings, and evaluated costs of maintaining the steel tank during its life.

Accurate cost estimates for prestressed concrete tanks are easily obtained. On standard tanks Preload or its Licensees will furnish estimates accurate within 5% based on current labor and material costs. With the price for the structure accurately determined, the Engineer can make his evaluation and comparison with other



2 MG water tank . . . 160' tower, 195' to overflow, Tyler, Texas

Two 13.0 MG reservoirs—292' ID x 27'4" SWD, Reading, Pennsylvania

Two 2.0 MG reservoirs—83' ID x 40' High to be backfilled asymmetrically with fill sloping from 40' to 20' on the wall, Commonwealth Water Company, Summit, N. J.

methods of design and construction and decide on which to use.

Contract documents may be prepared in several ways:

(1) If a decision is made to use a Preload tank, Preload will be glad to cooperate with the Engineer in preparing engineering plans and specifications to be included with the contract documents for issuance for bids.

(2) In lieu of (1) above, or if alternative methods of construction are decided on, then Preload will cooperate with the Engineer in preparing definitive specifications including detailed design requirements to be incorporated with the contract documents. Bidding contractors should file copies of design calculations and drawings with their bids.

(3) In special cases of alternative bids, and after Preload has had an opportunity to review the proposed alternative methods, it may be suggested to the Engineer that engineering drawings for the prestressed concrete tank should be prepared and issued in the interest of the client. In such case, Preload will assist in the preparation of such plans as in (1) above.

In some cases, the Owner has elected to negotiate with Preload for the furnishing of the prestressing work for the project for a lump sum price that represents a small percentage of the cost of the compiete tank. This price can be included in the contract documents with a stipulation to all bidding general contractors to include this sum as an allowance item in their bid. The general contractor will then engage Preload or one of its licensees as a sub-contractor for the specialized work. This procedure is particularly well suited to situations where only a Preload tank is desired.

Local material prices, labor rates and conditions will influence greatly the final bid price of a prestressed tank just as they do for any other construction. Since a Preload tank is constructed with formwork, concrete and reinforcing steel, over 75% of the contract price is spent in the local community for labor and materials. This should be an important point when steel tanks are being considered as the percentage of local expenditure is just about reversed.

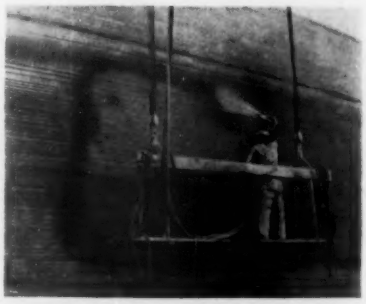
maintenance

Based on average U. S. conditions the larger capacity Preload tanks are generally more economical than conservatively designed reinforced concrete tanks. Smaller tanks may show no economy in initial cost but the advantages of prestressed design frequently justify the selection of a Preload tank. Preload tanks may cost slightly more in bare initial cost than ground storage steel tanks. However, steel elevated or underground tanks generally are more costly than comparable designs in prestressed concrete.

Since alternative methods may be considered, a complete economic evaluation must include the cost of maintaining the facility during the bond period of service life. In comparison with steel tanks, the cost of adequate regular maintenance becomes a substantial item of cost. Depending on local conditions, proper inspection, and maintenance, steel tanks will average 2.5¢ to 4¢ per square foot of maintained surface. This should include floor, interior and exterior surfaces of walls and roof. With column supported roofs the structural system involves a considerable area and should not be disregarded. It must be realized that prices will increase as they have in the past; therefore, the present maintenance dollar will have to be nearly doubled to represent the average cost for a 25 year period.

In summary, the Engineer and Owner should look on prestressing as another medium with which to build their storage tank, whether it be underground, surface or elevated. This is not a new material or concept; it is a recognized and accepted solution.

Wall will float on 5" x 12" x 2" rubber pads. Rubber water stops positively seal all construction and articulated joints.



Pneumatic mortar cover coating for wire protection.

THE PRELOAD COMPANY, INC.
- 211 East 37th St., New York 16, N.Y.
- 351 Jefferson, Dallas, Texas
- 711 Perimeter Road, Kansas City, Mo.

PRELOAD CONCRETE STRUCTURES INC.
837 Old Country Road
Westbury, Long Island, N.Y.

HERRICK IRON WORKS
28400 Clawiter Road
Hayward, Calif.

THE CANADA GUNITE COMPANY, LTD.
7325 Decarie Blvd.
Montreal 16, Canada

Elevated Tank Maintenance

by E. D. Barrett
District Sales Manager, Chicago Bridge & Iron Co., Detroit, Mich.

Years ago very little attention was given to preparation of the steel surfaces prior to painting in various shops, after fabrication and before shipment. Specifications always called for surface preparation to include removal of dirt, grease and loose mill-scale. Insufficient recognition was given to the fact that forming of steel always caused cracks in the mill scale; cracks that are minute and not enough to loosen the scale, but which are the starting points for later paint film failures.

Shop Paint

The shop paint coat was applied over this surface and the formed plates were shipped to the site. This was accepted practice and the majority of tanks built prior to 1946 were painted in this way. Since 1946 the industry has become conscious of the importance of clean, dry surfaces in preparation for painting. It is a fairly safe assumption that owners of tanks that have been built under this later thinking, using pickling or sand blasting to base metal, will have relatively less maintenance problems.

Consulting engineers and regular tank builders are therefore starting a "Preventive Maintenance" program at the source. However, all the engineers and tank builders can do from that point on is to advise and warn the owner. It is up to each community to provide for maintenance that will give trouble-free service.

During the development of designs of elevated tanks most items with moving parts have been eliminated so that all that is left is a program of regular inspection and painting.

It is hard for manufacturers to understand why so many owners neglect their elevated tanks. Almost all water departments set up meter repair programs, pump servicing, hydrant testing and pipe cleaning programs, but an elevated tank, a big item of original cost, is like a step child whose shoes are never shined.

So often a tank is painted on the outside for appearance with no inspection or painting being accomplished on the inside. As an example, one elevated tank in Michigan has had no inside paint for over 25 years.

Budgeting for Maintenance

All water superintendents have a big problem to overcome in setting up a budget and adhering to a sound "Preventive Maintenance" program. Municipal boards or commissions changes at regular intervals and few councils like to leave office with a record of having spent money for things that cannot be seen. Everyone would like to leave a monument indicating progress and growth. It is very easy therefore for board members to look up 100 feet in the air and say: "It looks to me as if it would last all right for another year or at least until after the coming election." This elimination of maintenance expense often occurs over many years; each succeeding board finding more interesting use for the scarce dollar and there are many tanks that have been uncared for during long periods of time.

On the positive side of the ledger one thing is of help to everyone. That is the fact that public bodies are becoming more conscious of the value of advertising. Boards are hopeful of growth and new tax paying industry; consequently, appearance is more and more important. The elevated tank is a prominent structure in any community and only a well maintained structure in constant service provides good advertising.

The outside of a water tank will usually receive better maintenance than the inside, but it is the inside that is most important.

Preventive Maintenance

Preventive Maintenance on elevated tanks consists of a very few items well planned. First, one should know the corrosive quality of the water. This will determine the frequency of inspection and care required. Surface water supplies and "soft" waters will usually require more frequent care than the harder waters from well supplies. A program of inspection every five years should be instituted where waters are high in oxygen content or are "soft." If the water is from deep well supply, a program of inspection every seven years should be satisfactory.

The second item on a maintenance program, after determining frequency, is the nature of the inspection. The accompanying printed form was developed after many years of experience in design and construction of tanks. The items covered by this report should all be covered. Experienced companies which build elevated tanks maintain regular inspectors and accomplish this inspecting on a low cost basis. There are also regular inspection companies whose services are for

W. & S. W.—Reference Number—1959

FORM G.O. 1

CHICAGO BRIDGE & IRON COMPANY

Inspection Report No. 3.

Inspection Contract No. _____ Original Contract No. _____

Location: Street _____

City _____ State _____

Present Owner _____ Original Owner _____

Capacity _____ Type Bottom _____ Height Bottom _____

Type Construction (Welded, Riveted) _____ Number Tower Panels _____

Year Built _____ Inspected By _____ Date of Inspection _____

REPORT OF INSPECTOR

1. Are anchor bolts rusted so as to materially reduce their strength? _____ If so, calliper and advise smallest section. If possible, examine carefully where bolts enter concrete. _____

2. Are anchor bolt nuts tight? _____

3. Are column shoes in good condition? _____. Are they clean and painted or has dirt accumulated? _____. If seriously rusted, state where and depth of rust. _____

4. Are the anchor bolt connections on standpipes and tubular columns in good condition? _____. Has their strength been materially reduced by rust? _____. If so, describe. _____

5. Are tower posts in line? _____. If answer is "no" describe condition _____

6. Is there any indication of settlement in the foundations? _____. If answer is "yes" describe condition. _____

7. Are tower rods in good adjustment and well tuned up? _____

8. Are tower rods in good condition? _____ If they are badly rusted so as to reduce strength, measure the smallest part and report. Be sure to state in what rods this occurs. Examine particularly condition of rods around pins. _____

9. Are there two cotter pins well spread in each end of all long pins and one cotter pin well spread in each up-set pin? _____ If rod pins with nuts are used, advise if nuts are on with full thread and the end of thread well battered. This is important. If cotters come out or nuts drop off, pins may come out with the result that tank bracing will be loosened and a collapse of the structure will result. EXAMINE EACH PIN _____

10. Is riser pipe or riser cylinder straight? _____

11. Are riser pipe or riser cylinder stay rods in good condition? _____

12. Is the frost casing in good condition? _____

13. Is the frost casing supported by substantial foundation? _____

14. Are there any indications of leaks in riser cylinder, or in riser pipe or in expansion joint? _____ Describe _____

15. Are there any indications of leaks in tank? _____ Describe _____

16. Is the ladder safe? _____

17. Is the balcony safe? _____

18. Is balcony floor in good condition? _____ State the amount of rust and how much dirt has accumulated thereon. _____

19. Report any bolts or rivets which are not in place in the splice connections of the tower, struts and balcony. (Missing bolts should be replaced by the inspector.) _____

20. State condition of paint and metal of tower. Look particularly inside of columns and struts, under lacing bars and post connections, at strut connections and at all more or less difficult and concealed places _____

21. State the condition of the paint outside tank and riser:

Large Riser Cylinder: _____
Bottom: _____
Shell: _____
Roof: _____

22. State the condition of the metal outside tank and riser:

Large Riser Cylinder: _____
Bottom: _____
Shell: _____
Roof: _____
Is finial connection solid? _____ If "No" describe. _____
Is the revolving ladder safe? _____

23. Was the tank emptied for inspection? _____ If not completely emptied, state how far down. _____

24. Is the tank equipped with a rust prevention system? _____
(a) If so, what type (suspended electrodes, outside anodes, etc.)? _____
(b) State name of manufacturer. _____
(c) When was system installed. _____

25. Is the tank now equipped with a float-type indicator? _____ If so, is it in good condition and working? _____

R-170

26. State the condition of the paint inside:
Large Riser Cylinder:
Bottom:
Shell:
Roof:

27. State condition of the metal inside:

Large Riser Cylinder:
Is cylinder pitted?_____ No. of pits per sq. ft._____. Describe pits as to size and depth.

Is pitting localized or general?
General Comments:

Bottom:
Is bottom head plate pitted?_____ No. of pits per sq. ft.
Are bottom bowl plates pitted?_____ No. of pits per sq. ft.
Describe pits as to size and depth. Head Plate
Bowl Plates
Is pitting localized or general
General Comments:

Shell:
Is 1st ring pitted?_____ No. of pits per sq. ft.
Is 2nd ring pitted?_____ No. of pits per sq. ft.
Is 3rd ring pitted?_____ No. of pits per sq. ft.
Is 4th ring pitted?_____ No. of pits per sq. ft.
Describe pits as to size and depth 1st ring_____ 2nd ring
3rd ring_____ 4th ring_____
Is pitting localized or general
General Comments:

Roof:
Is roof pitted?_____ No. of pits per sq. ft._____. Describe pits as to size and depth

Is pitting localized or general?
General Comments:

28. State condition of spider and spider rods.
29. State condition of inside ladder.
30. State condition of rivets at lap joints and at post connections.
31. State condition of metal between rivets at the laps and at the post connections.

32. Examine any valves and advise if leaking. This refers particularly to blow off valve, if furnished.

33. Is bottom covered with mud or scale?_____ If so, to what depth?
34. Does outlet pipe stick up above accumulations of scale?_____. Are there indications that some of this dirt and scale has entered the riser pipe?

35. Structure was last painted inside about_____ Type_____ Outside about_____ Color_____
Previous to that it was painted inside about_____ Type_____ Outside about_____ Color_____
Previous to that it was painted inside about_____ Type_____ Outside about_____ Color_____

36. General Statements as to condition of structure.

37. Repairs made by Inspector.

38. Repairs recommended.

39. Inspection report should be sent to

Signature of Inspector

Date

A GOOD APPROACH to a sound preventive maintenance program is to have a regular inspection of elevated tanks. The number of years between inspections depends on several factors. This form, as shown on these two pages, lists a number of questions pertinent to a proper inspection.

INVESTIGATE THE METHOD OF

Before you

Shown here is the inside of a storm sewer after cleaning and with steel mesh in place ready for applying Gunite.

ONLY GUNITE OFFERS YOU:

GREATER STRENGTH. Due to the low water ratio of Gunite the structural strength is almost double that of hand poured cement.

GREATER WEATHER AND FROST RESISTANCE. Because of its high density, penetration of water and other destructive agents are held to a minimum.

RESISTANCE TO HEAT AND CHEMICAL ATTACK. Due again to high density Gunite is more resistant to alkali and acid attack than ordinary cement.

LOW COST. Where the basic structure is sound, renovating with Gunite can be considerably less costly with no sacrifice in strength or permanence.

With the walls and ceiling finished the sewer takes on the appearance of new construction with structural strength much greater than that of ordinary construction methods.

Write direct to Pressure Concrete Company, 1555 Helton Street, Florence, Alabama, for 48-page Booklet and complete information on Gunite.

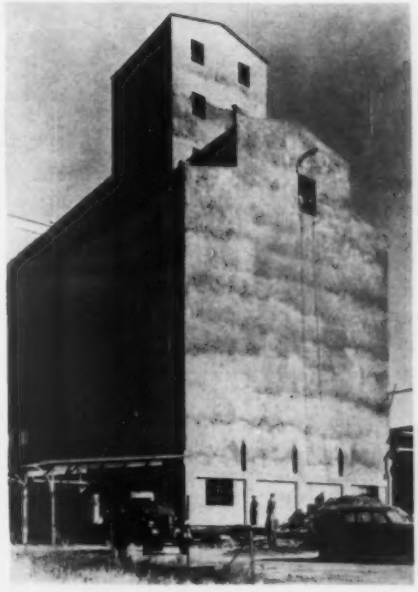
These two pictures give an excellent view of Gunite being applied pneumatically to a river lock structure. Note that Gunite is applied over a thoroughly cleaned and sand blasted surface. The finished structure will actually be sounder than new.

"GUNITE"

CONSTRUCTION

BUILD • REPAIR or RENOVATE!

"GUNITE" IS THE MODERN METHOD (SAND AND CEMENT APPLIED PNEUMATICALLY) OF REPAIRING, CONSTRUCTION AND LINING: RESERVOIRS — DAMS — FILTER PLANTS — TANKS — SEWAGE DISPOSAL PLANTS — STADIUMS — BRIDGES — SEA WALLS — SWIMMING POOLS — ALL TYPES BUILDING.

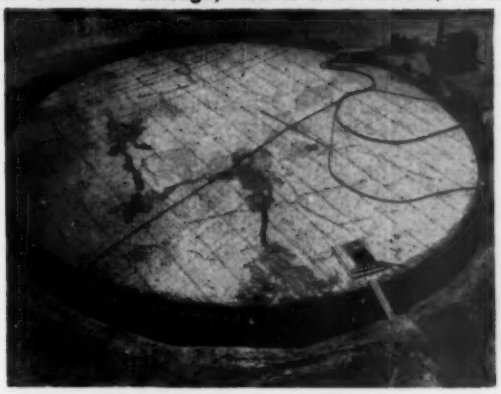


Buildings too, such as this grain elevator can be efficiently renovated with Gunite.

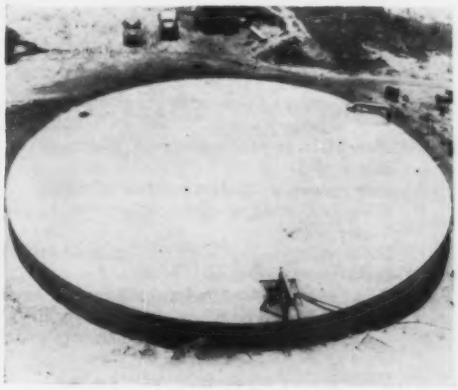
PRESSURE Concrete Co.

1555 Helton Street FLORENCE, ALABAMA

Other Offices: **Chicago, Illinois and Newark, N. J.**



This huge concrete tank has undergone a thorough cleaning, with reinforcing mesh already in place, it is ready for applying "Gunite."



The finished product is now ready for many more years of use and at a fraction of the replacement cost.

hire and who will provide experienced men for the job.

The next step is following the recommendation of the report. Corrosion or deterioration of steel structures can be minimized or even eliminated by regular care. There are two accepted methods of inside tank maintenance. One is by painting, the other is by the use of properly designed cathodic treatment. Since the latter is a special field, only painting will be discussed here.

Sound Painting Practice

The one condition that hurts good painting practice is the fact that few municipalities can take a tank out of service long enough to properly dry out the inside. Everyone knows that paint will blister or will not properly bond if the surface is not completely dry. Therefore one should plan on a minimum of one week for drying time and then only if both top and bottom manholes are off in order to induce a good movement of air. A blower placed in the opening of the manhole in the riser will speed up air movement and drying time.

Careful preparation of surfaces by the painter is the next important item. Be sure that all loose paint is removed and all surfaces wire brushed. Surface preparation usually requires about 80 per cent of the total time taken for a one coat job if the work is carefully accomplished.

All bare areas should be spot painted after being cleaned to bright metal. This spot paint must be allowed to dry properly before any final paints are applied. Paints with excessive "driers" added are not the answer. Only time will do the job if a good bond is to be expected. The biggest problem is the small tank because painters can clean, spot and final paint all in a week when two to three weeks is the minimum time for the job because of proper drying.

Next, do not put a tank back in service for at least a week after inside painting. Drying time again is required for good results.

With reference to paint materials, a superintendent should acquaint himself with the specification prepared by AWWA. A group of experienced men took the time to gather evidence and came out with the material set forth. There is no cure-all, no miracle paints or coatings that have proven superior to this AWWA specification. If improvements in coatings appear both the AWWA and the tank builders will be the first to say so.

Ordinances

In order to budget and program well planned "Preventive Maintenance" it might be necessary to consider positive means to that end.

If a community sees the importance of such action, an ordinance can be written requiring a sinking fund to be set up and used at certain specified times for inspection and maintenance, and no doubt, such a condition could be inserted into each bond issue requiring such sinking fund and regular use for "Preventive Maintenance."

In general, water works men should back away from laws and rules forcing them to accomplish things but in this case with changing councils and boards it may be the only way to accomplish proper care of the structure.

As to actually required repairs: the repairs of any magnitude are on old riveted tanks and this point is important; no repairs or replacements of parts in contact with water should be made unless an actual leak appears. If a leak does occur, the contractor who built the tank should be called in. He has detail plans and experience and all regular builders of tanks want to be helpful in such cases. There is no standard procedure for making repairs. Inspection, engineering experience and actual construction experience are required in each case to come out with the proper answer for the least over-all cost.

Modern design, improved original preparation and priming with high quality paint materials will produce longer trouble-free service in elevated tanks.

Shown at the end of this article is a questionnaire sent to C B & I customers who purchase water spheres. This questionnaire produces the reasons for the purchase, the service, and the manner in which the owners intend to keep it in good condition.

Questionnaire on
Maintenance Practice on Watersphere

1. (A) What is the nominal capacity and height of your Watersphere?
   (B) What service does your Watersphere provide?
   Municipal water storage ——
   Industrial general service ——
   Industrial fire protection ——
   Primary source for fire protection ——
   Secondary source for fire protection ——
2. How often do you inspect your Watersphere, or have it inspected?
3. (A) Have you established a painting schedule?
   (B) If so, how often do you paint or plan to paint your Watersphere?
   (C) Inside sphere? (D) Outside sphere?
   (E) Inside pedestal and base frustrum?
4. What kind of paint have you found to be the best for your locality and how do you apply it?
5. Do you have painting done by your own maintenance crew or by outside contractor?
6. What is your approximate painting cost?
7. (A) Do you protect the interior of the tank with cathodic protection?
   (B) If so, what type of anode do you use (material) and what is the current setting?
   (C) Name of Manufacturer?
8. (A) Do you have a service contract to check the cathodic-protection setup?
   (B) If not, how often do you check on anodes and current?
9. Have you landscaped the area around your Watersphere to blend it in with surrounding areas?
10. (A) If so, what have you done—planted trees, shrubbery, lawn?
    (B) What does its maintenance cost annually?
11. What maintenance has been necessary on heating facilities if any have been installed in your Watersphere?
12. What other maintenance have you found to be necessary?
13. (A) Do you have pumping equipment, softening unit, chlorinating equipment, etc., installed in the base? If so, what are they?
    (B) What do you store or keep in the flared base of the column?
    (C) Where would you store such material or equipment without such a housing?
14. General comment.

Sizing Water Service Piping

by ARTHUR RYNDERS

Superintendent of Water Works, Department of Public Works, Milwaukee, Wis.

Revised specifications for water service piping were recently issued by the Milwaukee waterworks. Formerly, the specifications for service piping were incorporated in a publication entitled, "Rules, Regulations and Rates." The revised specifications, discussed herein, are concerned with the complete and exclusive subject of water service piping.

Water service piping is defined as the piping from the water main to and including the valve on the discharge side of the water meter. The piping from the valve on the discharge side of water meter to its terminus is defined as building piping and is beyond the scope of this specification.

Liberal sizing of the underground service pipe is encouraged, with a view to the future requirements of the customer. When the size of the service pipe is liberal the friction loss for the complete installation can be reduced by replacing the original meter with a larger meter, or by replacing part of the original building piping with larger piping, either or both of which can be done at a lower cost than installing a larger underground service pipe. Experience indicates that customers' requirements usually increase rather than decrease.

For simplicity in tabulating friction loss, the service piping was divided into (a) the service pipe, including all stops, valves, and fittings, and (b) the water meter. Friction loss tables are included in the specifications for both (a) and (b).

The specifications are arranged for the use of plumbers in estimating and installing future jobs. It is believed that if the tables for sizing service piping contained in these specifications are used, the plumber, the plumbing inspector, the water tap permit clerk, and all others concerned will have a common reference which will produce a satisfactory installation for the customer. The specifications also cover service piping for fire protection systems, but the sizing of this piping is outside the scope of this paper.

The specifications are divided into four parts. Part I, General, is divided into chapters on Definitions, Authority of the Commissioner, Special Notices and Permits, and Sizing of Water Services. Part II, Materials, has only one chapter; namely, Materials. Part III, Installation, is divided into chapters on Excavation, Connection, Piping, Structures, Backfilling, Sidewalk and Pavement Replacement, and Meter Setting. Part IV consists of Tabulations and Drawings.

Much of the early work of preparing these specifications was in the preparation of drawings. A few of these drawings are discussed briefly in the following.

Figure 1 shows tap service piping, copper, ¾ to 2 in. in diameter. The limits of the service piping, the location of the curb stop and considerable fabrication detail are shown.

Attention is called to the table at

Table 1

Supply Units for Various Types of Fixtures*

Type of Fixture	Control	Supply Units	
		Public	Private
Closet	Flush tank	5	3
	Flush valve	10	6
Urinal	Flush tank	3	--
	Flush valve	5	--
Bathroom group	Flush tank	--	6
	Flush valve	--	8
Shower	Mixing valve	4	2
Bath tub	Faucet	4	2
Lavatory	Faucet	2	1
Laundry trays	Faucet	--	3
Service sinks	Faucet	3	3
Hose connection	Faucet	6	3
Kitchen sink	Faucet	4	2
Dishwasher	Automatic	2	2
Garbage disposal	Automatic	2	2
Washing machine	Automatic	4	3
Air cond. (per ton)	Automatic	2	2

*Adapated from Nat. Bur. of Standards (BMS79).

Table 2
Estimated Flow for Total Supply Units*

Total Fixture Supply Units		Est.
With Flush Tanks	With Flush Valves	Flow, gpm
12	----	8
16	----	12
23	----	16
31	----	20
41	8	25
54	13	30
86	28	40
127	48	50
174	75	60
225	109	70
300	195	85
375	250	100
475	350	120
580	490	140
690	625	160
935	925	200
1,380	1,380	250
1,750	1,750	300
2,660	2,660	400
3,650	3,650	500

*Adapted from Nat. Bur. of Standards (BMS 79).

Table 3
Service Piping Selections for Various Flows

Flow, gpm	Service Pipe		Friction Loss, psi		Pressure, psi	
	Length, ft	Accept. Sizes	In Service Pipe	In Meter	At Meter Outlet	At Main
8	60	¾ x ⅝ SD	6.8	0.6	27.6	35
		1 x ⅝ SD	1.8	0.6	32.6	35
		1 x ¾ SD	1.8	0.4	32.8	35
		1½ x ¾ SD	0.3	0.4	34.3	35
	80	¾ x ⅝ SD	8.7	0.6	25.7	35
		1 x ⅝ SD	2.2	0.6	32.2	35
		1 x ¾ SD	2.2	0.4	32.4	35
		1½ x ¾ SD	0.3	0.4	34.3	35
	100	¾ x ⅝ SD	10.6	0.6	23.8	35
		1 x ⅝ SD	2.7	0.6	31.7	35
		1 x ¾ SD	2.7	0.4	31.9	35
		1½ x ¾ SD	0.4	0.4	34.2	35
12	60	1 x ⅝ SD	3.8	2.2	29.0	35
		1 x ¾ SD	3.8	1.1	30.1	35
		1½ x ¾ SD	0.6	1.1	33.3	35
	80	1 x ⅝ SD	4.7	2.2	28.1	35
		1 x ¾ SD	4.7	1.1	29.2	35
		1½ x ¾ SD	0.8	1.1	33.1	35
	100	1 x ⅝ SD	5.7	2.2	27.1	35
		1 x ¾ SD	5.7	1.1	28.2	35
		1½ x ¾ SD	0.8	1.1	33.1	35
16	60	1 x ⅝ SD	6.5	4.5	24.0	35
		1 x ¾ SD	6.5	2.1	26.4	35
		1½ x ¾ SD	1.0	2.1	31.9	35
	80	1 x ⅝ SD	8.1	4.5	22.4	35
		1 x ¾ SD	8.1	2.1	24.8	35
		1½ x ¾ SD	1.3	2.1	31.6	35
	100	1 x ⅝ SD	9.8	4.5	20.7	35
		1 x ¾ SD	9.8	2.1	23.1	35
		1½ x ¾ SD	1.5	2.1	31.4	35

the lower left of Fig. 1. Optional combinations of service pipe and meters are shown. The service pipe ranges in diameter from ¾ in. to 2 in. The meters range in size from ⅝ in. to 1½ in. The sizes of stops and valves are shown for each combination.

Figure 2 shows the number of full threads engaged between the corporation stop and the side wall of the water main. A minimum engagement of 4 full threads was considered reasonable, below which a threaded clamp is attached to the main. Taps above the zigzag line require clamps; taps below the zigzag line do not.

Figure 3 shows a meter setting of the basement type for ⅝, ¾, and 1 in. meters for copper or lead service piping.

Figure 4 shows a meter setting of the basement type for 3, 4, 6, 8, and 10 in. meters on cast-iron service piping. The usual, as well as optional, meter setting arrangements are shown.

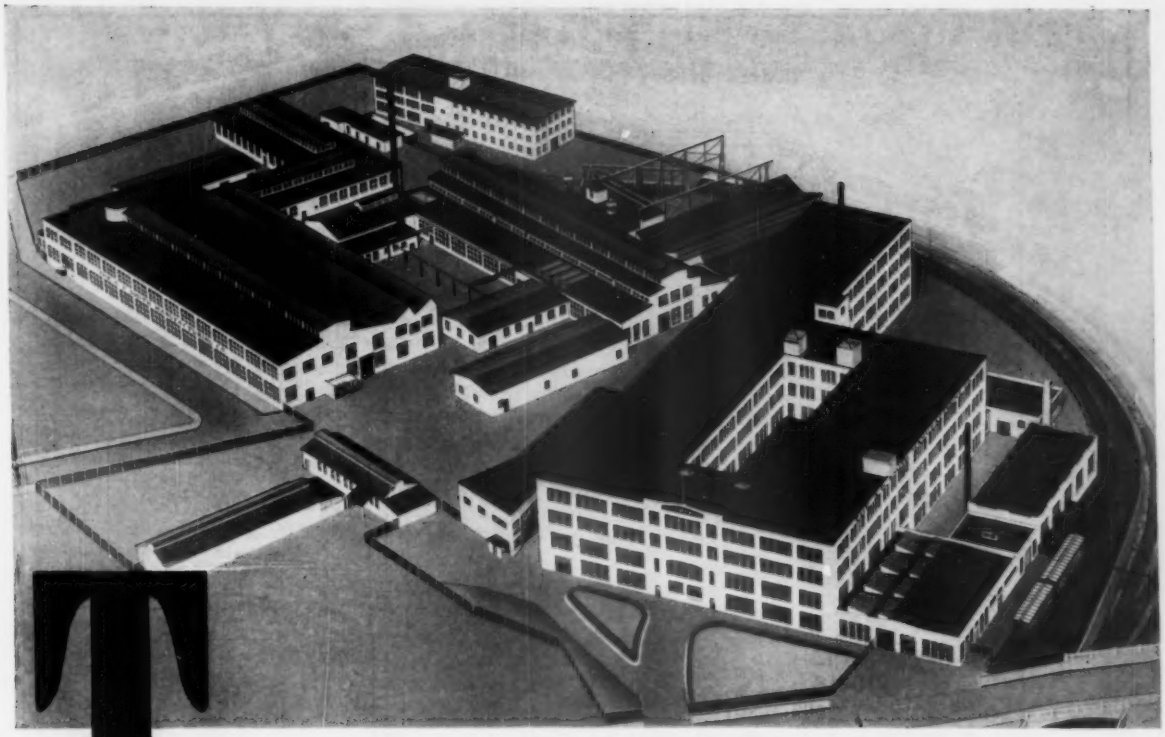
Altogether, 35 drawings are included in the specifications. These drawings show trench and tunnel bracing, clearances for tapping, all tap and branch service piping installations normally permitted, all basement and pit meter settings normally permitted, details regarding the construction of meter pits complete with trap doors or manholes, piping diagrams for domestic supplies and for the combined domestic supplies and private fire protection systems normally permitted.

After the work of preparing the drawings was well advanced the subject of sizing the service piping was taken up. The best reference on this subject was considered to be the National Bureau of Standards Report BMS-79. This reference recognizes a difference in the use of plumbing in public and private buildings. The reference also recognizes a difference between closets, urinals, and bathroom groups equipped with flush tanks and those equipped with flush valves. All the usual types of fixtures found in both public and private buildings are rated in terms of fixture supply units.

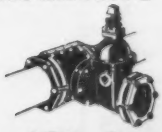
G-10-1 (see Table 1) is a tabulation of fixture supply units for both public and private buildings. Note that in a private building a lavatory with the usual faucet control has a rating of one fixture unit, whereas in a public building it has a rating of two fixture units. All fixtures listed have apparently been carefully rated in fixture supply units, depending on installation in public or private buildings. With this tabulation it is easy to total the fixture supply units in any given building once the number and type of fixtures is known.

Having the total number of fixture supply units, the flow in gallons per minute can be estimated from Table 2.

Having the estimated flow, the length of service pipe should be considered. Table 3 is typical of the tables which simplify this consideration. Obviously, the length of the service pipe will make a difference, particularly in the smaller sizes shown for each flow. The loss shown for the service pipe includes the loss through the corporation stop, the curb stop,



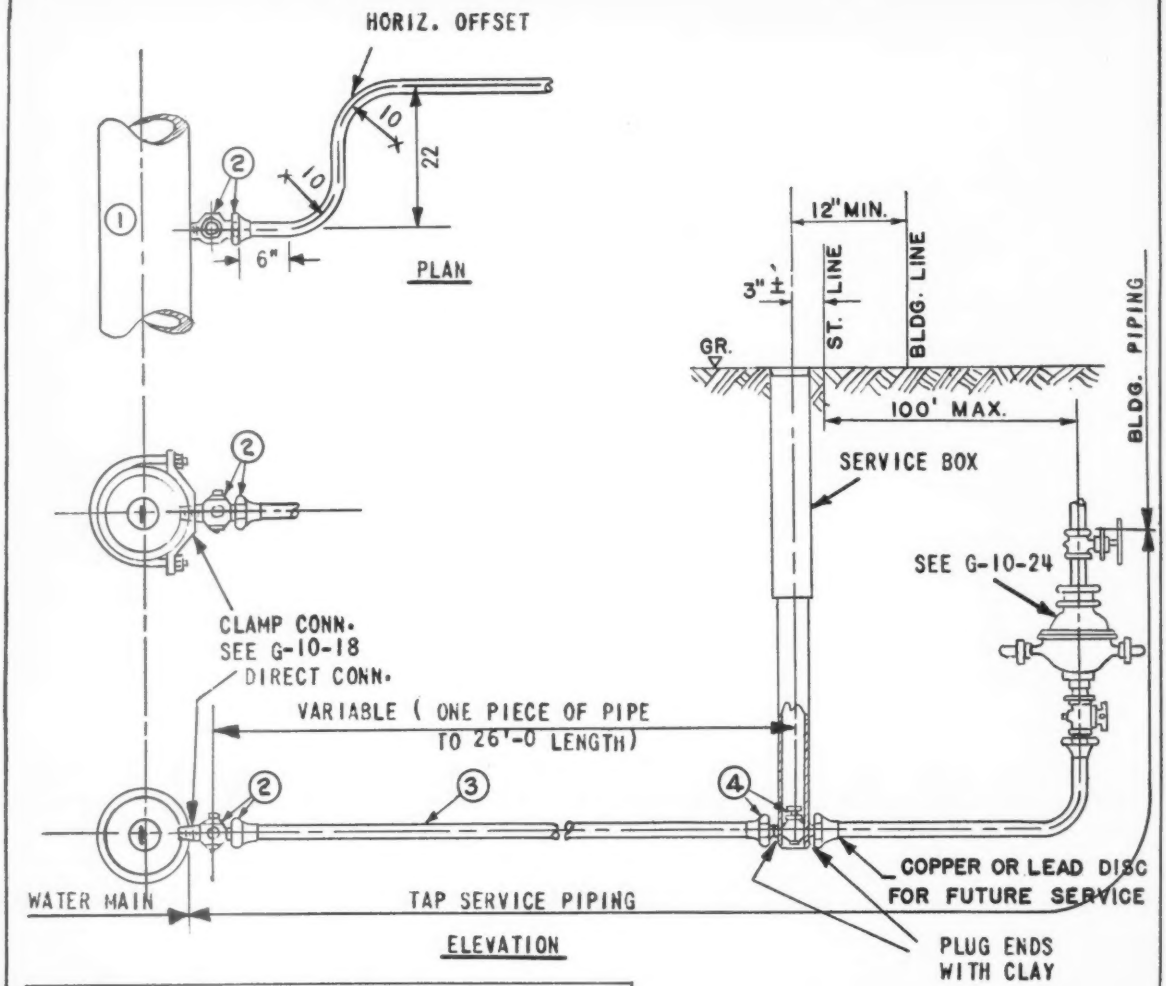
THE A. P. SMITH MANUFACTURING CO.

produces, **FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types.** **GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service.** **INSERTING VALVES sizes 4" thru 48" for inserting under pressure.**  **TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.**

FIRE HYDRANTS · VALVES · SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY



NO.	ITEM
①	WATER MAIN
②	CORP. STOP - COPPER CPLG.
③	COPPER TUBE - TYPE K
④	CURB STOP - COPPER CPLG. BOTH ENDS

SER. PIPE	CORP. STOP	CURB STOP	METER STOP	METER	METER OUTLET VALVE	METER HORN
3/4	3/4	3/4	3/4	5/8	3/4	3/4X5/8
1	1	1	1	5/8	1	1 x 5/8
1	1	1	1	3/4	1	1 X 3/4
1-1/2	1-1/2	1-1/2	*1-1/2	3/4	1-1/2	♦1x3/4
1-1/2	1-1/2	1-1/2	*1-1/2	1	1-1/2	♦1 x 1
2	2	2	* 2	1	2	♦1 x 1
2	2	2	* 2	1-1/2	2	NONE

* GATE VALVE ♦ BUSH SEE G-10-26

NOTE-

SERVICE PIPING TO BE APPROXIMATELY LEVEL FROM MAIN TO PROPERTY LINE

CITY ENGINEERS OFFICE
MILWAUKEE, WIS.
MILWAUKEE WATER WORKS

TAP SERVICE PIPING
COPPER

H. Stammann — ENGINEER
E. A. Schmuck — CITY ENGINEER

DRAWN W.S
CHECKED O.A.H.
FILE 3-5-1
DATE 5-13-57
SCALE 3/4" 1"
DWG. G-10-20

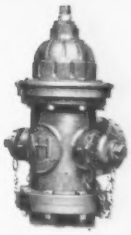
FIG. 1—TAP service piping, copper—¾ in to 2 in.

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

(Subsidiary of Walworth)

The letters M & H are the sign of quality on Valves, Hydrants and Pipe Line accessories. High quality materials, simplicity of design and expert workmanship have established for M & H enviable reputation for dependable service in the water works and sewage fields and for industrial uses. M & H products are modern in design, with many exclusive M & H features.



Right: Standard Model Hydrant

M & H VALVES AND FIRE HYDRANTS

M & H A.W.W.A. Gate Valves are furnished double disc parallel seat, or solid wedge, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2" to 36". Low Pressure and High Pressure Valves and Square Bottom Valves are an established part of the M & H line.

M & H Compression Type Hydrants conform to latest specifications of the American Water Works Association. They are available either in standard, flush type or traffic models. Hydrants with 5¼" and 6¼" valve opening are listed and approved by Underwriters Laboratories of Chicago and Associated Factory Mutuals of Boston and A.W.W.A. Hydrants with 4¼" and 4½" valve opening are A.W.W.A. approved only.

Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

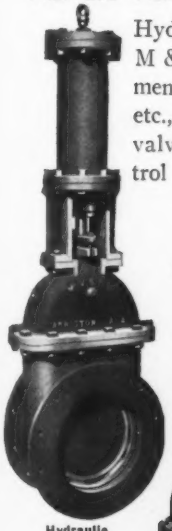
Gate Valve

Traffic Model Hydrant

FILTER PLANTS & SEWAGE PLANTS

Hydraulically and electrically operated M & H Valves are used in sewage treatment plants, water works, filter plants, etc., to save time and labor since these valves can be operated by remote control for quick, easy closing or opening. They are also used as emergency valves to admit higher water pressures into the mains in case of fire. Sizes 2" to 36" A.W.W.A.

M & H Flap Valves and Shear Gates are iron body, bronze mounted, used in Filtration and Sewage Disposal Plants.

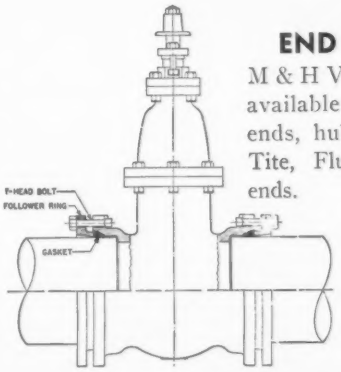


Hydraulic Gate Valve

Low Pressure Gate Valve Non-Rising Stem

END CONNECTIONS

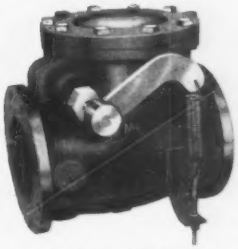
M & H Valves and Hydrants are available with Mechanical Joint ends, hub ends, flanged, Ring-Tite, Fluid-Tite and Universal ends.



FIRE PROTECTION

M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

Rising Stem Gate Valve



Spring Check Valve

Indicator Post

M & H PRODUCTS INCLUDE:

WALL CASTINGS	FLANGED FITTINGS	TAPPING SLEEVES AND VALVES
CHECK VALVES	FLOOR STANDS	SPRING LEVER CHECK VALVES
EXTENSION STEMS	SHEAR GATES	MUD VALVES
FLAP VALVES	B & S FITTINGS	FLANGE AND FLARE FITTINGS
CUTTING-IN VALVES & SLEEVES		CUTTING-IN TEES

MAIN DIA.	CAST IRON PIPE SPEC.	STANDARD SIZE SERVICE NUMBER OF FULL THDS. ENGAGED			
		.3/4" TAP	1" TAP	1-1/2" TAP	2" TAP
4"	M-38	3.22	2.76	.92	-.57
	250	3.92	3.36	1.50	-.09
	C	5.18	3.84	2.87	.80
6"	M-38	3.92	3.36	1.84	1.15
	250	4.90	4.20	3.45	1.84
	C	6.02	4.60	4.46	2.64
8"	M-38	4.90	3.84	3.45	2.53
	250	6.02	4.80	4.14	3.22
	C	6.72	5.52	4.83	3.91
12"	M-38	5.74	5.16	4.83	4.14
	250	7.42	6.60	6.09	5.63
	C	8.68	7.20	6.67	5.98
16"	M-38	7.56	6.36	5.98	5.63
	250	9.80	8.16	7.82	7.59
	C	10.50	9.76	8.16	8.05
20"	M-38	12.89	11.04	10.29	9.77
	250	11.76	9.84	8.20	8.97
	C	8.96	7.44	7.01	6.67

ABOVE ZIGZAG LINE - TAP WITH CLAMP
BELOW ZIGZAG LINE - TAP DIRECT

NOTE - MIN. OF 4 FULL THDS. REQUIRED FOR DIRECT TAP.

MATERIAL SPECIFICATIONS-
M-38 CITY OF MILWAUKEE SPEC. DATED 7-5-51
250 CLASS 250 - FED. SPEC. WW-P-421
C CLASS C - A.W.W.A. SPECIFICATION
TAPS - CORP. STOPS, A.W.W.A. TENT. SPEC. 7T. 1-7 TABLE I
M-42 CITY OF MILW. SPEC. DATED 10-7-53
SERVICE CLAMP

CITY ENGINEERS OFFICE
MILWAUKEE, WIS.
MILWAUKEE WATER WORKS

TAP WITH CLAMP
OR TAP DIRECT

A. Rynders ENGINEER Lloyd D. Knapp CITY ENGINEER

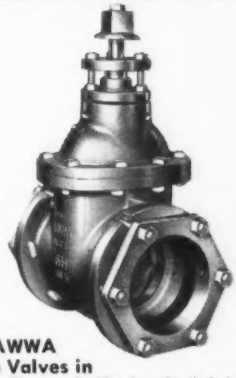
DRAWN
CHECKED O.A.H.
FILE 3-5-1
DATE 3-18-52
SCALE
DWG. G-10-18

FIG. 2—NUMBER of full threads engaged between the corporation stop and the side wall of the water main.

IOWA

meets your most exacting specifications

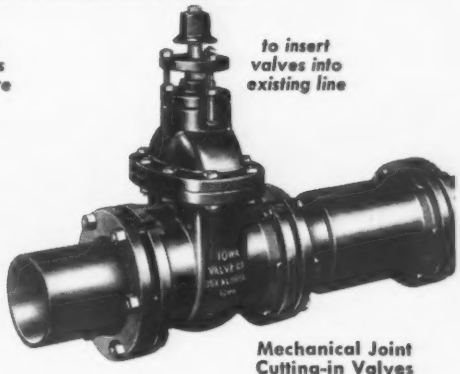
FOR FLOW CONTROL: *in distribution and fire protection systems*



AWWA
Gate Valves in
Hub, Flanged, Mechanical Joint

to connect branch mains under pressure

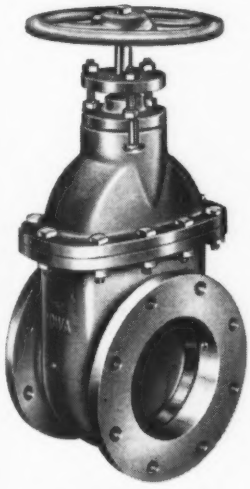
Mechanical Joint
Tapping Valves
and Sleeves



to insert valves into existing line

Mechanical Joint
Cutting-in Valves
and Sleeves

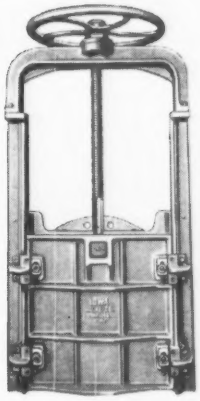
FOR FLOW CONTROL: *in sewage treatment and water filtration plants*



Flanged Gate Valves
2" through 42"

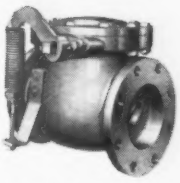
Flap Valves

Plug Drain Valves



Sluice Gates

Shear Gates



Check Valves

Square-Bottom Valves

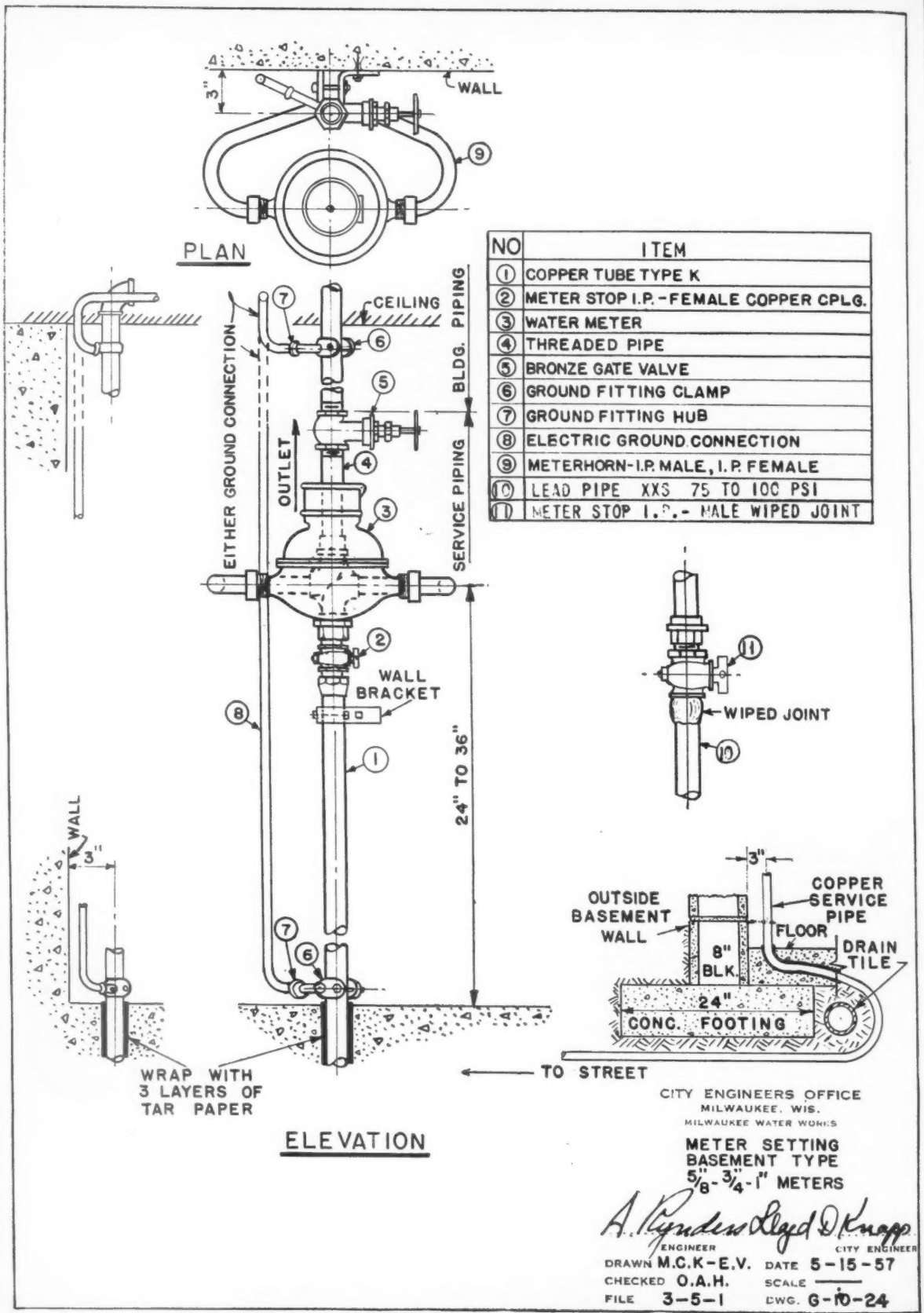
Few manufacturers can match *Iowa* in offering such a wide variety of valves, accessories and specialties for water filtration and sewage treatment plants, as well as for water distribution systems. It will pay you to call in an *Iowa* man before placing your order!

IOWA VALVE COMPANY

Oskaloosa, Iowa • *A Subsidiary of James B. Clow & Sons, Inc.*

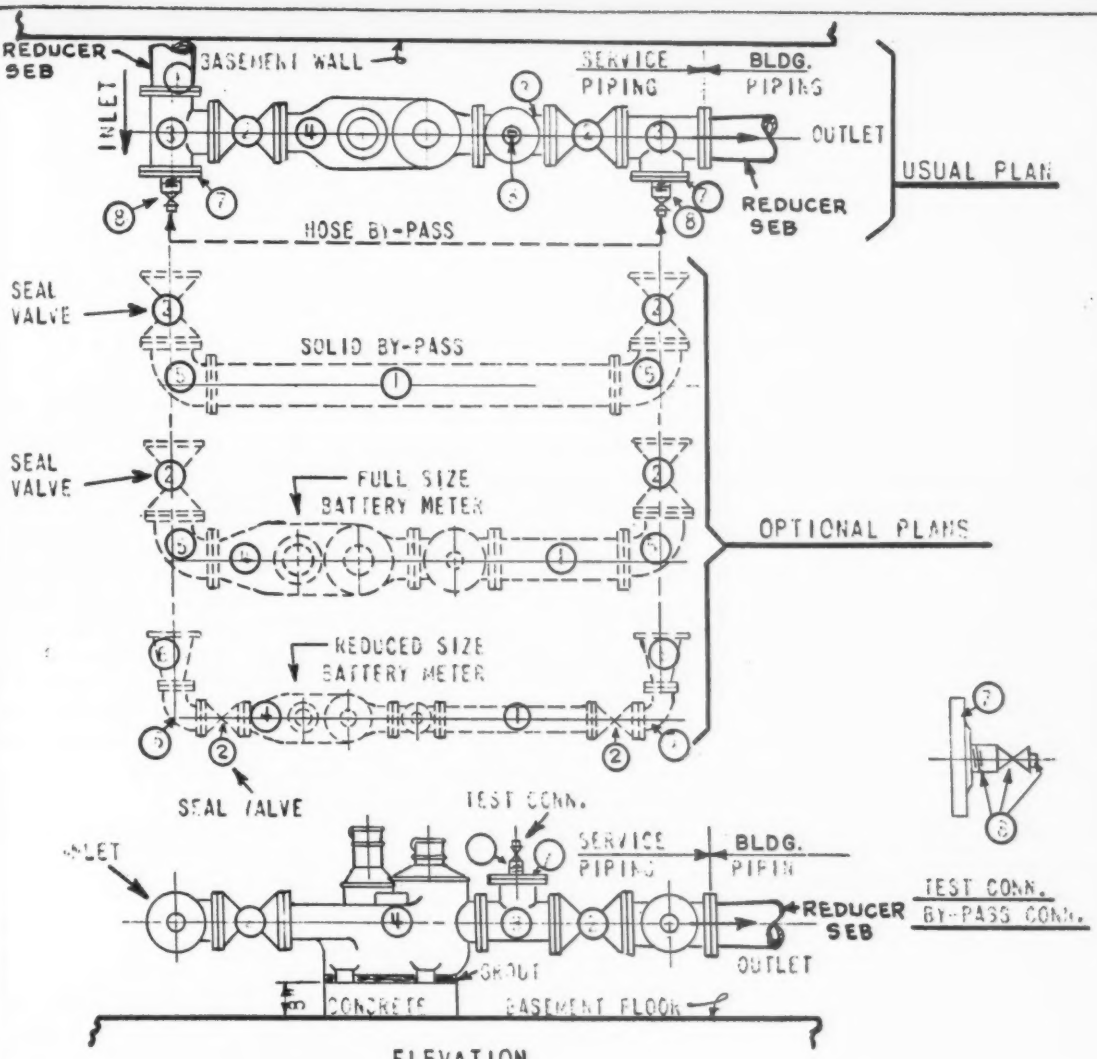
Since 1909 a reliable source for precision engineered products

catalog on request



NO	ITEM
1	COPPER TUBE TYPE K
2	METER STOP I.P.-FEMALE COPPER CPLG.
3	WATER METER
4	THREADED PIPE
5	BRONZE GATE VALVE
6	GROUND FITTING CLAMP
7	GROUND FITTING HUB
8	ELECTRIC GROUND CONNECTION
9	METERHORN-I.P. MALE, I.P. FEMALE
10	LEAD PIPE XXS 75 TO 100 PSI
11	METER STOP I.P.- MALE WIPED JOINT

FIG. 3. METER setting of basement type (⅝ in., ¾ in., 1 in.) for copper or lead service piping.



NO.	ITEM
1	C.I. FLANGED STEEL PIPE
2	GATE VALVE - R.S. & Y.
3	C.I. TEE
4	WATER METER
5	90° C.I. ELL
6	C.I. TAPER REDUCER
7	REDUCING FLANGE
8	NIPPLE - GATE VALVE - BR. PLUG 2" G.V. FOR 3"-4"-6" METERS 3" G.V. FOR 8"-10" METERS

NOTE: ALL FLANGES 125 LB. STD.
ALL STEEL OR W.I. FITTINGS
TO BE GALVANIZED

CITY ENGINEERS OFFICE
MILWAUKEE, WIS.
MILWAUKEE WATER WORKS
METER SETTING
BASEMENT TYPE
3"-4"-6"-8"-10" METERS

A. Rynders — ENGINEER
Lloyd D. Knapp — CITY ENGINEER

DRAWN J.R.S. DATE 5-13-57
CHECKED C.A.H. SCALE -
FILE 4-5-1 DWG. G-10-30

FIG. 4—METER setting of basement type (3 in., 4 in., 6 in., 8 in., 10 .) on case iron service piping.

and all valves and fittings in the meter setting.

Also, having the estimated flow, the size of water meter should be considered. The loss shown for the meter includes only the loss through the meter itself.

It will be noted in Table 3 that the pressure at the outlet of the meter is shown for various combinations of sizes of service pipe and meters. The pressure at the outlet of the meter is calculated on the basis that the minimum pressure in the main will not drop below 35 psi, which is considered to be a reasonable minimum pressure for the utility to maintain in the main at street grade. It should also be recognized that the utility may, from time to time, find it desirable to alter some of its service districts as long as minimum pressures do not drop below 35 psi. Also, on the basis of 35-psi pressure in the main, the size of service piping recommended in these tables, and reasonably sized building piping, adequate pressures will be available for use at all fixtures in buildings not more than two stories high.

Presently, actual pressures in the Milwaukee distribution mains vary from 105 psi to something below the 35 psi chosen as a basis here. Actual pressure at the outlet of meters will vary through even wider limits. The regulation of pressures at the outlet valve of the meter is not considered to be a function of the service piping, but rather a function to be incorporated in the building piping by the use of pumps, reducing valves, or other means.

It will also be noted in Table 3 that several options are shown for water service size. As previously stated, all of the options shown are acceptable; they are intended for the use of the plumber in figuring costs of various acceptable installations and agreeing with his principal upon a particular installation.

To review and summarize, the steps in sizing water service piping using the proposed specifications are as follows:

1. Determine from the building plans whether the building is public or private.
2. Determine from the building plans whether flush tanks or flush valves are to be used.
3. From the building plans list all the fixtures to be supplied through the water service piping.
4. From Table 1 determine the number of fixture supply units and the total.
5. From Table 2 determine the estimated flow in gallons per minute.
6. Using this or the next larger estimated flow, select from Table 3 the length of service pipe nearest the length shown on the plans. Note the alternate sizes of service pipe and meters which are acceptable.

Acknowledgements

The author wishes to acknowledge the work of O. A. Halvorson, Mechanical Engineer, Water Construction Division, who compiled most of the specifications; W. McIntyre, Supt. of Meter Division, who contributed much practical information; Ralph F. Weber, Executive Secretary, Milwaukee Plumbing Contractors Association; Robert T. Flint, Supt. of Bureau of Plumbing Inspection; John Wilkenson, Engineer, Fire Insurance Rating Bureau; and many others who also contributed by reviewing and commenting on these specifications.

Auxiliary Beacon Lights

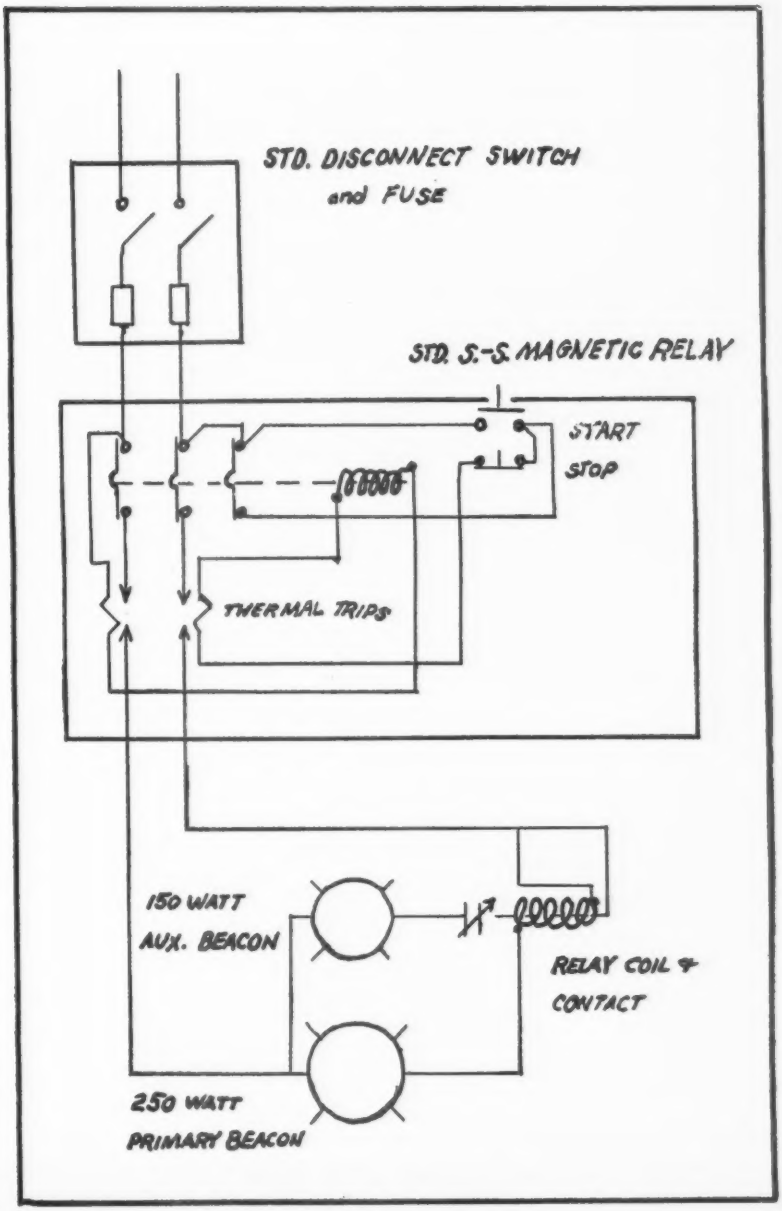
by PAUL C. ZIEMKE
Clinton, Tenn.

Auxiliary beacon lights which light automatically have been accepted with zeal by electrical men who have had to climb elevated storage tanks at midnight to repair lamps. A stand-by lamp eliminates this need and still assures due warning to low flying aircraft. The automatic cut-in of the auxiliary beacon upon failure of the primary guards against any interruption in service.

The diagram illustrates a simple means of employing a standard two line 160 Volt, A.C., 60 cycle Stop-Start magnetic relay with thermal trips and a standard disconnect switch and fuse installation. The arrangement allows for the ordinary overloads which might inadvertantly develop on the conduit run or in the lamp enclosure.

A relay holding coil and "normally closed" (N.C.) electrically operated contact can be installed in series with the primary beacon. These items may be obtained from any electrical supply house, however, care must be taken to select a holding coil which will give approximately the same current flow through the lamp and the coil. Under this arrangement, when the primary lamp fails the relay holding coil is de-energized and the contact closes. The circuit to the auxiliary lamp is, therefore, closed and the lamp lights automatically.

If the auxiliary lamp is of a different wattage than the primary, plant guards or other night personnel will notice the difference in brightness and report the failure. Maintenance can then be completed as the schedules permit.



CIRCUIT diagram for auxiliary beacon.

Flow of Water From Hydrants

by D. S. DAVIS

Head, Dept. Pulp and Paper Technology, University of Alabama, Tuscaloosa, Ala.

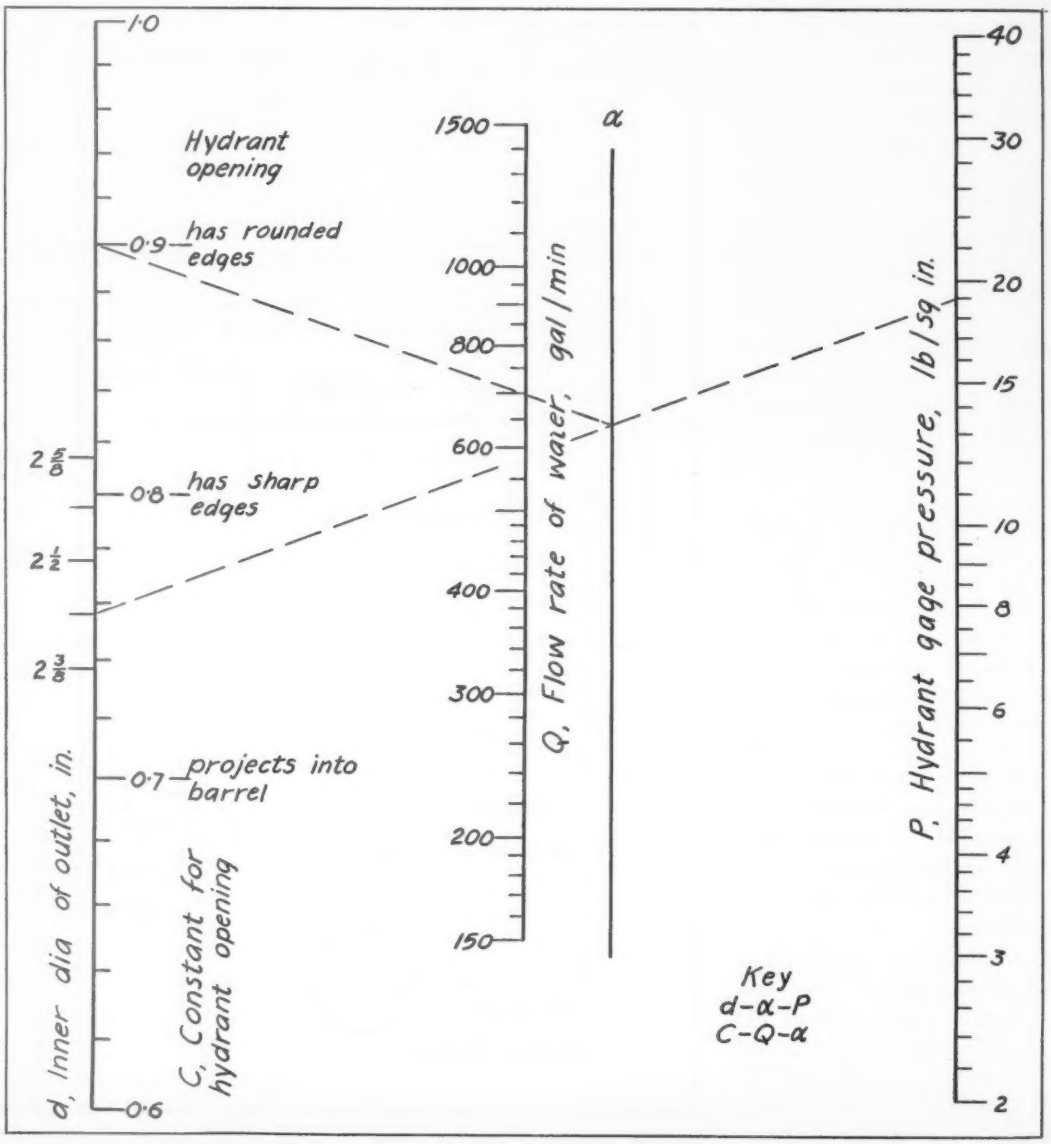
The rate of flow of water through outlets at hydrants in city mains is given by the equation[2]: $Q = 29.83\ C\ d^2\ P^{0.5}$; where Q = rate of flow of water, gal/min; C = orifice constant for the hydrant opening (0.9) when the hydrant opening has rounded edges where it leaves the barrel; 0.8 when the edges are sharp; and 0.7 if the butt projects into the barrel of the hydrant at all; d = inner diameter of the outlet, inches; and P = gage pressure (during flow) at the hydrant, lb/sq in.

The nomograph, constructed by means of established methods,[1] enables rapid and accurate solution of the equation. The use of the chart is illustrated as follows: What is the rate of flow of water from a hydrant in a city main when the inner diameter of the outlet is 2-7/16 inches, the hydrant opening has rounded edges, and the gage pressure at the hydrant during flow is 19 lb/sq in.? Follow the key; connect 2-7/16 inches on the d-scale and 19 on the P-scale with a straight line; note the intersection with the α-axis. Connect this point and 0.9 (for rounded edges) on the C-scale with a straight line; read the rate of flow on the Q-scale as approximately 700 gal/min.

References

(1) Davis, D. S. "Nomograph and Empirical Equations," Chap. 6, Reinhold Publishing Corporation, New York, 1955.

(2) Water Works Engineering, *111* No. 3, 230 (1958).



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Layout of Meter Maintenance Shop*

by DAVID J. FORD

Asst. Sales Mgr., Ford Meter Box Co., Wabash, Ind.

MANY water works men are faced with the task of laying out a new meter-testing shop or improving the arrangement of an old one. The numerous advantages to be gained from the use of proper equipment, well located in the space available, justify careful study and planning. The following suggestions on what to use and where to place it may be of some help.

Meter shops range in size from those for repairing and testing a few dozen meters a year to some which work on more than 10,000 annually. In addition to the number of meters, other conditions that can affect the size, equipment, and layout of the shop include:

1. Number of makes and types of meters used, which governs the size of the repair part stock and the storage space for it.
2. Local water quality, which determines the extent of corrosion, liming, incrustation, and wear.
3. Location and type of meter settings, which control the condition of the meter register and the outside of the casing. The repair of frozen meters is sometimes a tremendous job in certain meter shops. In other localities, meter casings become caked with mud, and, when the dial glass is broken, the entire register may be mud clogged.
4. Local practice of state requirements specifying how often meters shall be tested.
5. Customer ownership of meters, which calls for special care in identifying and segregating meters so that they can be returned after testing.
6. Existence of special cleaning practices in refurbishing meter casings during the process of repair and testing. Whether done by wire brushing, acid dipping, sand blasting or painting, special equipment is required.

In planning the equipment and layout of any meter shop, some or all of the above factors must be borne in mind. Possibly more important than any of them is the trend toward increased numbers of meters and toward more frequent repair as they become older. All planning should be done with an eye to the future.

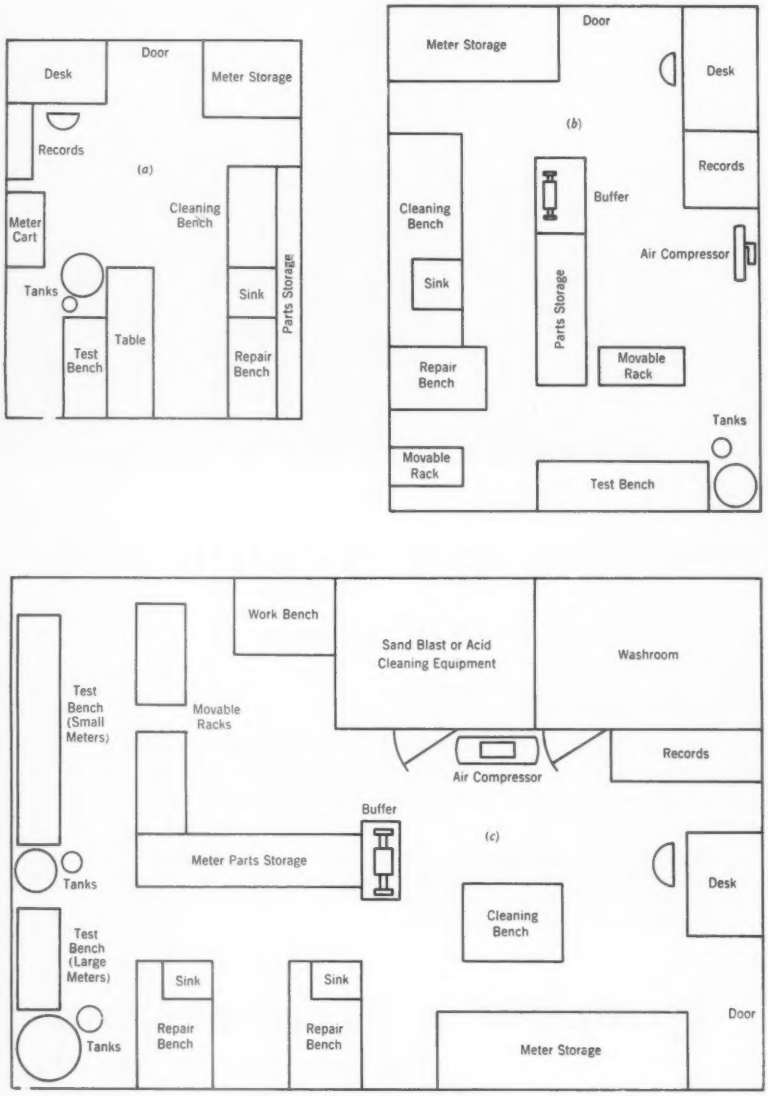


Fig. 1. Suggested Shop Layouts
Key: (a) 12 x 15 ft; (b) 15 x 20 ft; (c) 30 x 20 ft.

Selection of Equipment

The basic equipment, exclusive of a desk or file for meter records, is listed below. The most essential items are given first, followed by those which would be justified only in large shops:

1. An accurately calibrated tank, or a plain tank on an accurate scale, to check the meter being tested against the actual volume causing a given registration. Drainage piping for the tank (or tanks) should be of sufficient size to empty it quickly.
2. A substantial workbench with vise, hammer, wooden or leather mallet, screwdrivers, wrenches, pliers, files, scrapers, wire brushes, and other tools.

*Reprinted from the Jour. Amer. Water Works Assn.; Vol. 46, No. 6 (June 1954) by permission of AWWA.

3. A sink with running water, preferably both hot and cold, for washing meters and parts.

4. A test bench for domestic-size meters (through 1 in.). Although meters can be connected up with ordinary fittings, there is a saving in time and effort if a test bench is used for smaller meters, which probably constitute up to 99 per cent of the total tested. The number of test units on the bench would be governed by the volume of work. Series testing is generally economical. For more efficient testing, benches may provide for hydraulic clamping of meters and automatic shutoff of flow at the proper tank level.

5. A rate-of-flow indicator.

6. An electric grinder, with wire brush and buffer, which has a wide variety of uses.

7. Storage bins or drawers for meter parts.

8. An adapter for testing 1¼-, 1½-, and 2-in. meters. This accessory, which can be attached to the test bench, provides ease of testing of larger meters at a minimum investment.

9. A small air compressor. Only experience will indicate the many ways in which compressed air is convenient for cleaning, drying, painting, and similar operations.

10. A bench drill press or an electric hand drill, a widely useful device. Electrical outlets should be conveniently located.

11. Chemical cleaning equipment. Experts disagree greatly on the advisability of using acids or other chemicals on meter parts. The cleaned pieces, especially when treated with acid, have a fine appearance but may be slightly reduced in size, so that meter performance is affected. When chemical cleaners are used, precautions must be taken to prevent health hazards. Proper rinsing facilities and exhaust fans should be provided.

12. A test bench for 1¼-, 1½-, and 2-in. meters. When enough large meters are to be tested, a special bench for one or more of them is a good investment. Calibrated tanks large enough to hold water for tests run at high rates of flow are also desirable for quantity testing of large meters.

13. An electric or air-driven impact wrench. This provides for the speedy removal of large meter casing bolts.

Lack of equipment need not result in poor testing of small meters. With an accurate tank, a watch, and a few valves and fittings, it is possible to do a thorough testing job. Some or all of the additional items listed above will, however, increase efficiency and are usually a good investment.

Shop Layout

After the amount and type of equipment to be included in the meter shop have been decided upon, attention should be given to proper placement in the allotted space. There are a number of requirements to be satisfied and a good many valuable principles to be applied. The arrangement adopted should provide the best flow of meters through the shop. The distance between adjacent stations should be short, and easy methods of moving the meters should be available.

Basically, a meter in the shop follows this general routing: the incoming meter is tested and stored; next, it is washed and disassembled; the parts are cleaned, nonserviceable parts are replaced, and the meter is reassembled; then it is taken to the test bench and given the required tests; if its accuracy is within the limits prescribed, it is sent to outgoing storage; if further repair is necessary, the meter is returned to the repair bench, and part of the cycle is repeated.

The nature of this cycle suggests the necessity for good material-handling practice to simplify as much as possible the physical work involved. This objective can be approached by:

1. Locating the meter shop on the ground floor. This eliminates elevators and speeds up supply.

2. Arranging for a loading dock near the door of the meter shop. This also will shorten the distance supplies

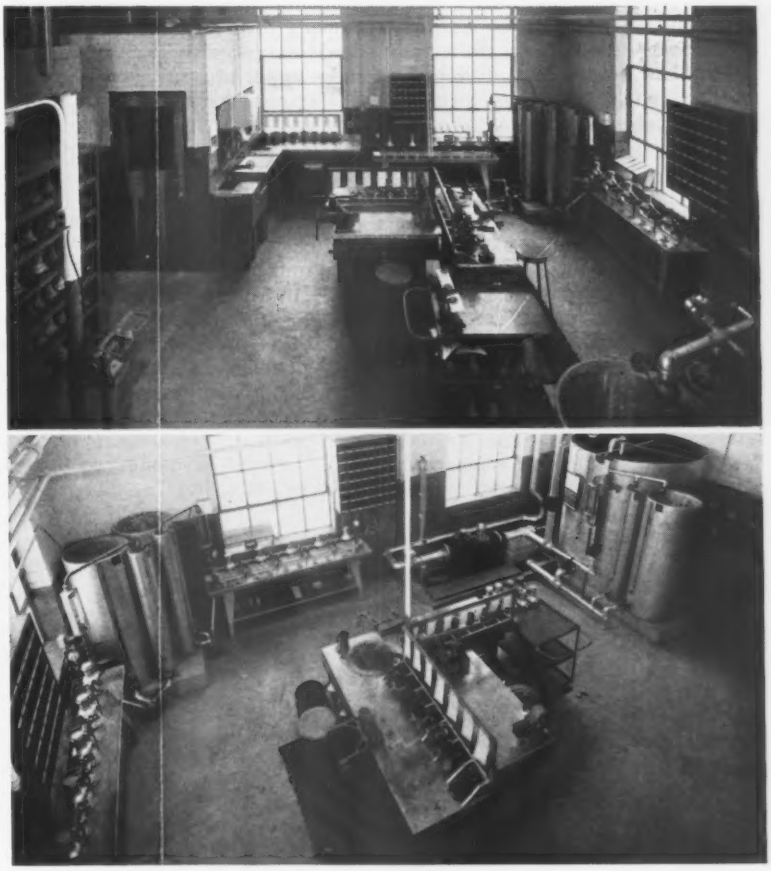


Fig. 2. Two Views of Wichita, Kan., Meter Shop

In the top photograph, the storage racks are visible in the left foreground, with the grinder and buffer a little to the right; at rear left is the acid cleaning room, flanked by a sink and workbench; test benches and tanks for small meters are at rear right; in the right foreground, part of the large-meter testing equipment can be seen; at center are other workbenches, with a portable rack for small meters in front of them. The lower photograph, taken from atop the acid room, gives a good view of the small-meter test benches and the center workbenches. Behind the large-meter tanks at right rear, the drill press is partly visible. The shop area is approximately 625 sq ft.

must travel.

3. Maintaining good lighting, either natural or artificial, throughout the shop. Work tables should be arranged so that the light from the windows does not shine into the repairman's eyes. Good operation in a meter shop depends upon the ability of the workmen to see what they are repairing, inspecting, or testing—jobs in which clear vision is all important.

4. Providing for both hot and cold running water. Washing meter parts with hot water and soap is the most harmless method in use and is sufficient for many parts. Hot water is essential, especially in cold weather.

5. Locating a motor-driven buffer near the repair bench. It is important to have this machine within a very few steps of the repairman, to avoid continual walking. The buffer should be equipped with a dust collector or exhaust.

6. Washing the exterior of dirty meters when they begin the processing cycle. This practice will improve working conditions by producing a much cleaner meter shop.

7. Making compressed-air hoses available to both the repairman and the meter tester.

8. Providing storage space for both incoming and outgoing meters near the door. There they can be easily counted and readily moved in or out.

9. Placing the meter record file near the door and the meter storage area.

10. Keeping commonly used parts on the repair bench and storing other parts nearby for easy access.

11. Avoiding extensive paper work in the parts checkout procedure. Time will be saved and the repairmen will be appreciative.

12. Equipping the shop with carts or rolling racks to be used for moving meters from one station to another and for storing meters. Each rack or cart should hold a specified number of meters so that quick inventory can be taken. It should be easy to reach every meter and read its tag. In a small shop, ten meters per cart would be enough; in a large shop, 100 meters arranged on a rack would be more efficient. It may be desirable to provide facilities for hooking meters on the rack in a vertical position. With that system, each meter is on the outside of the rack and can be removed or examined without disturbing any other. Dock facilities can be arranged so that an entire rack filled with meters can be rolled alongside a track for loading, thus eliminating one handling operation. The benefits from mobility of meters should not be underestimated; any practice that will speed up the processing cycle is worth serious consideration.

It is usually impossible to adhere closely enough to theory to attain the ideal layout, chiefly because existing facilities impose limits upon the designer. It is cheaper to work such facilities into the layout than to alter them to fit the ideal. It may, however, be worth while to compare the cost of changing the existing facilities with the value of the increased efficiency made possible. The features affecting meter shop design include: shape and size of room; existing piping; location and size of windows, doors, and columns; size of available equipment, such as filing cabinets and workbenches; and availability of space for meter and parts storage outside the room. The latter condition can be an advantage if there is not enough space inside the room for storage. Otherwise, to have the storage in another room means wasted steps every time a part or meter is moved.

The three suggested layouts illustrated (Fig. 1) serve to demonstrate the principles mentioned previously. The prevailing conditions determine the layout. In the small-shop layout (Fig. 1a) the meters move clockwise about the room with only short distances between adjacent stations. The layout in Fig. 1b provides more storage space, a buffer, more bench space, and a larger test bench. For larger cities, the arrangement in Fig. 1c provides for two separate repair benches, two test benches—one for smaller meters and one for meters larger than 1 in.—a cleaning room, and a washroom. Movable racks are shown in all three layouts. Figure 2 illustrates an actual layout.

Meter shop layouts embodying the principles of efficient material handling, using proper equipment, and having real regard for the workman's needs can definitely save time as well as labor.

Acknowledgment

The author wishes to acknowledge gratefully the many helpful ideas gained through consulting and corresponding with E. J. Good, Indiana Gas & Water Co., Lafayette, Ind., and with H. W. Niemeyer and A. McCauley, Indianapolis Water Co., Indianapolis, Ind.

How to Increase Revenue

Without Raising Water Rates

by RAYMOND F. BISHOP

Superintendent, Board of Public Works, Bonnville, Mo.

WATER METERS constitute a type of mechanism common to all water departments, whether they have large or small plants, surface water or ground water sources, or just pump the water to a tower or storage basin.

These meters, because of their very function, may be considered as "employees" of the department. Just as insurance companies depend on their local agents to make monthly collections, the grocer depends on his cash register to record every sale, and the service station owner depends on his gasoline meters to register the smallest delivery accurately, water departments depend on their meters to record accurately and completely, the smallest—and the largest— delivery of their product to the customer. In fact, in most cases it is the meters that record the revenue that pays for wages, repairs, replacement of worn out equipment, construction of new mains, and the many other things involved in operation of a water system.

Mechanical Employees

These mechanical "employees," however, are usually looked at only once a month, and then only to read the accummulated revenue, not to check their efficient functioning. In many instances poor functioning of a meter is never detected until it ceases to function at all, despite the fact that long before many meters turn over for the last time they fail to register that small flow of one gallon per minute or less. In other words, it has become an ill employee who is only working part-time.

Proper meter maintenance is an obvious remedy. A properly maintained water meter is an accurate device and as such is fair to both the customer and city alike. In any event the chances of the customer being overcharged are negligible, as a neglected disc-type water meter usually runs slow rather than fast.

In other words, if the meter is not registering the small flows (and that is the most common defect), a ¼-gpm leak in a toilet flush box will cost the department 360 gpd, or 10,800 gallons per 30-day month, or 130,000 gallons per year.

Many meters that have been in service for five years will not register this flow. Nevertheless, from 11 to 15 per cent of all water used in private homes flows at a rate of ¼ gpm or less, and 25 per cent at 1 gpm or less. Without this low-flow registration a dripping faucet may cost the department 5,000 gallons per month.

One city provided a startling example of the foregoing point. This city removed forty ⅝-inch meters that had been in service five years and made a flow test on them. Of these, 36 would not move at all on

SMALL BUT EFFICIENT meter repair shop makes for efficient use of pumped water and provides for full revenue collection.

Ed. Note: This paper was presented by the author at all the district meetings of the Missouri Water & Sewage Conference and at the annual joint meeting of the Missouri Sect. AWWA and the Conference. It was released for publication in *Water & Sewage Works*

TABLE I

Free Water Furnished Customer When Meter Registers Inaccurately

Meter Registration, %	Water Furnished Free	
	Days per Year	Gallons per 1,000 Gallons Used
95	19	50
90	38	100
85	57	150
80	77	200
75	97	250
70	105	300
65	129	350
60	146	400
55	164	450
50	182	500

the ¼-gpm flow and the remaining four were completely dead on both the ¼-gpm and the 1-gpm flows. Why should a homeowner call a plumber for that dripping faucet or leaking toilet flush box when his meter will not register the flow caused by the leak?

Another city found a 57 per cent loss of water. A leak survey was made and other steps were taken to find this unaccounted-for water. Finally, all meters were brought in for test. Many were completely dead; 15 to 20 per cent were found to be slow. After testing, cleaning, and repairing, the meters were replaced in the system; all but 18 per cent of the filtered water was accounted for, with a net gain of $4,000 in the first five months.

Other Costs Involved

Although pumping cost increases are an important factor necessitating reduction of water system losses, there is another important element—the savings in chemicals, machinery wear, etc., not only in the water plant, but also in the local sewage plant—when these waste losses are cut to a minimum.

All meters should test at least 90 per cent on the ¼-gpm flow. Surveys show that more than 2,000 mil gal daily of water are wasted or otherwise unaccounted for in this country each day. Most of this could be controlled by proper metering and adequate maintenance. Any local water shortage or sizeable waste flow calls for a complete meter testing program to determine where the excessive flows are and to insure proper payment for the water used.

No meter should be in service more than ten years: the average should be five years, depending on the type of water in the system. Metering alone is not enough: Installation of a meter does not mean the end of all troubles; as metering efficiency decreases, revenue and net earnings go down. It is at this point that most people begin to think about increasing water rates, whereas many times it would only be necessary to inaugurate and maintain a proper testing and meter repair program, which should be an integral part of any water system.

Water meters are mechanical and, therefore, need attention. It is not easy, usually, to get the city officials to raise water rates, but they will buy test equipment and meter repair parts.

Results of Meter Maintenance

A meter testing program was set up at Boonville, Mo., several years ago with the goal of removing, testing, cleaning and repairing all meters. At the time this article was written 1,100 of the 2,000 meters had been tested and repaired. The maximum service time was 32 years, the minimum five years, and the average ten years. The average results for these 1100 meters were as follows:

Flow Rate	Accuracy
12 gpm	82%
1 gpm	71%
¼ gpm	52%
Average	68%

This meant a loss in water and revenue of 32 per cent.

At an average cost of $6.25 per meter for parts and labor, meters were removed, cleaned, repaired, tested and replaced. Tests after repair indicated the meters to register as follows:

Flow Rate	Accuracy
12 gpm	100%
1 gpm	101%
¼ gpm	99%
Average	100%

At present rates in Booneville this meant a saving in water of 32 gallons for each 100 gallons used, or an actual gain in revenue of 1.6 per cent for each 100 gallons delivered. The minimum charge is $1.13 for 2,250 gallons, and with the unrepaired meters this meant that although 2,970 gallons were being delivered only 2,250 gallons were being paid for. In other words, customers were being given free, 720 gallons per month. The revenue thus lost amounted to $0.36 per month on each minimum customer. Projecting this over the 1,100 meters repaired, based on the minimum bill, the savings in water was 825,000 gallons per month, or a net monthly gain in revenue of $412.50.

This leaves no doubt as to the importance of a meter maintenance program, even in a small system.

How much water is a water utility giving away each month? Table I gives the amounts of water given away without revenue for each meter under various conditions of meter inaccuracy. Obviously, this may be a large proportion of a system's water shortage. As mentioned previously, more than 2,000 mgd of water are being wasted across the nation.

Summary

It is recommended that any water superintendent know his water meters, and keep a record of each including the date installed, size, flow, serial number and location. Also, when the meter is removed for test that a record be made of its flow before cleaning and after cleaning and repair, its time in service, the amount registered between tests, the parts used, the reason for test, and the total cost of repairing and replacing.

Water is cheap—too cheap—but not so cheap that it should be thrown away.

Pressure Losses in Water Meters

By D. S. DAVIS

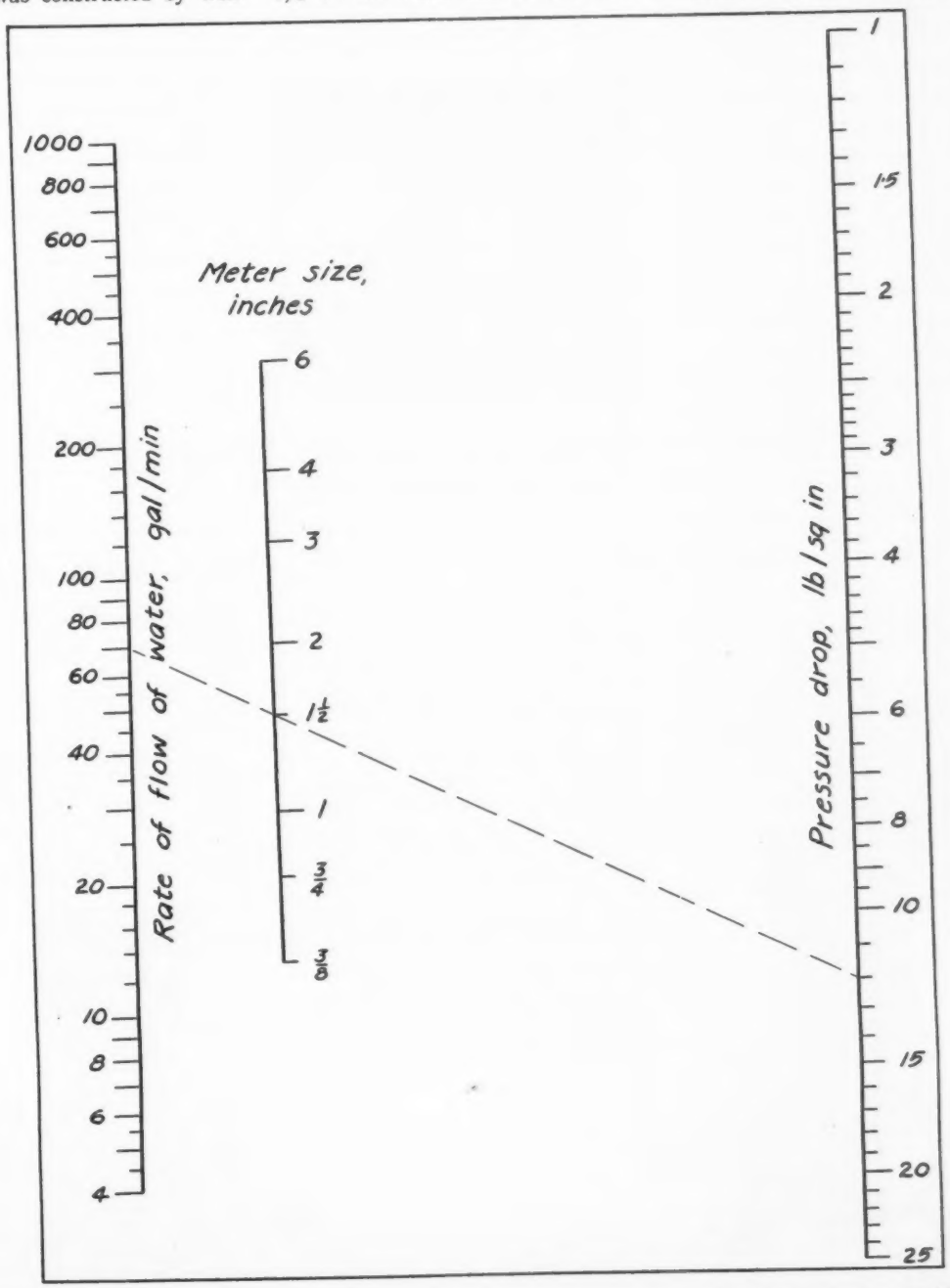
Head, Dept. Pulp and Paper Technology, University of Alabama, Tuscaloosa, Ala.

Mathews,[1] in the AWWA Journal, presented data on the pressure drops through water meters at various rates of flow. This logarithm of pressure drop in linear with the rate of flow was used in the construction of the accompanying line coordinate chart. The chart was constructed by well-known and standardized methods.[2]

An example of how the chart works is illustrated by the following: Q. What pressure drop may be expected in a 1½ in. water meter when the rate of flow of water is 70 gal/min? A. Connect 70 on the rate scale and 1½ on the meter size scale with a straight line. The extension of this line, upon meeting the pressure drop scale shows the loss to be 12 lb/sq in.

References:

1. Mathews, C. M., Journal, American Water Works Assn., 49 (9) 1911 (1957).
2. Davis, D. S., "Nomography and Empirical Equations," Chap. 10, Reinhold Publishing Corp., New York, N. Y., 1955.



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For over 60 years, more Trident meters have been purchased than any other make. Most of these . . . even the oldest . . . are still running accurately. This long serviceable life means lower amortization, obsolescence and replacement costs.

Trident meters have long led the field in design improvements, and today are the finest, most modern meters available. Every improvement has been made to fit all older Tridents. This is one of Trident's biggest advantages.

A planned schedule of testing and repair with Trident meters gives you a continuous program of meter modernization . . . at far less cost than scrap-and-replace methods. Repairs take less time, too, aided by Trident's extreme simplicity. A moderate stock of only the *latest* parts services *all* your Tridents. You waste no time searching or waiting for parts for old meters. Trident parts are *always* available. Your repair men have no obsolete models to learn. If they can repair one Trident, they can repair all . . . efficiently, economically.

TRIDENT METERS FOR DOMESTIC SERVICES IN COLD OR WARM CLIMATES

Trident meters combine fine-instrument construction with the inherent high accuracy achieved only in disc-type, positive displacement water meters. Accurate at all rates of flow within normal test flow limits and remarkably sensitive to small flows.

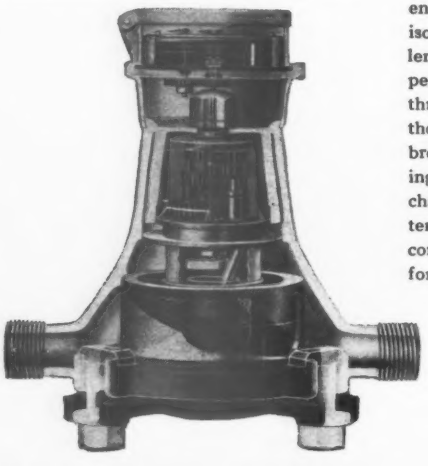
Trident Frost-Proof Meter embodies the original frost-proof meter feature. If the water freezes and expands, the cast iron bottom cap breaks, relieving the working parts from strain. The bottom cap can be replaced at very nominal cost. For warm climates, the Trident Split-Case Meter is recommended.

Among exclusive features for long accurate life are: Gear train is fully oil-enclosed, including the stuffing box, to isolate vital parts from abrasives, turbulence, corrosive elements, and to provide permanent lubrication. Anti-friction thrust roller absorbs disc thrust, making the Trident virtually immune to disc breakage. Heat-proof, hard rubber bushings in gear train and register are interchangeable. Sand ring keeps abrasive material out of working parts. Materials are corrosion-resistant, with special materials for unusual corrosion problems.

Easy to service and repair . . . makes big savings in meter costs over the years. Register has no screws. Chamber is snap-joint. Disc is in three parts, easy to adjust. Guide pins, slots, etc., assist in assembling meter properly.

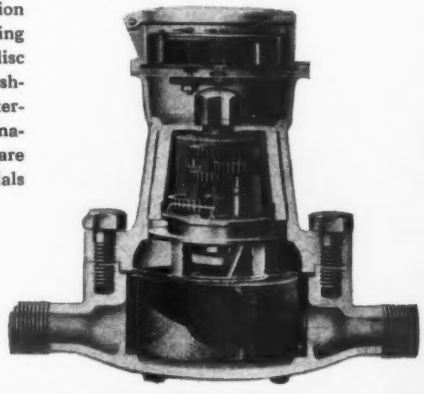
Trident Frost-Proof Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
5/8	10¾	7½	5½	9	1¾	20
5/8 x ¾	11½	7½	5½	9	1¾	20
¾	15	9	6	9	1¾	30
1	26	10¾	9⅜	9⅜	2	50
1 x 1¼	26	10¾	9⅜	9¾	2	50



Trident Split-Case Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
5/8	9	7½	5	8	1	20
5/8 x ¾	9½	7½	5	8	1	20
¾	12	9	5⅝	8⅝	1⅛	30
1	20	10¾	7½	9	1⅝	50
1 x 1¼	20	10¾	7½	9	1⅝	50

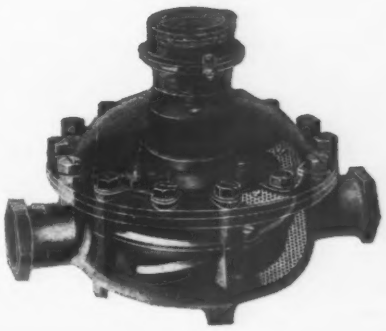


NEPTUNE METER COMPANY

STYLE 3 TRIDENTS FOR MEDIUM RATES OF FLOW

A disc-piston meter for commercial and other installations requiring medium rates of flow larger than household consumption, but not great volumes. Also excellent for "battery" settings where preferred for metering wide flow ranges. In addition to sensitivity on low flows inherent in disc meters, it has the Trident oil-enclosed gear train, heat-proof removable bushings in register and gear train, interchangeable parts and other Trident features which give it sustained accuracy and low maintenance cost. On 1½" and 2" sizes, a "delivery adjustment" can be regulated in relation to line pressure to prevent racing.

These two sizes of Style 3 Meters do the work of any compound meter of equivalent size and, being simpler, they do it with less cost for maintenance and repair.



Trident Style 3 Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	36	12⅝	10	10⅝	2⅜	100
1½ Flge.	40	13	10	10⅝	2⅜	100
2 Scr.	58	15¼	12 3/16	11¾	3¼	160
2 Flge.	61	17	12 3/16	11¾	3¼	160
3 Flge.	105	24	16 3/16	17⅞	3⅞	300
4 Flge.	257	29¼	22 1/16	20 5/16	4¾	500
6 Flge.	589	36¾	29	25⅜	5⅞	1000

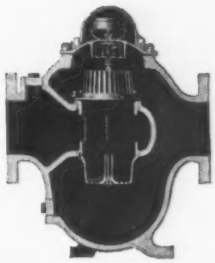
CREST METERS FOR BULK WATER DELIVERIES

For "bulk" water deliveries at periodic or continuous high rates of flow—i.e., where mains deliver water to adjacent townships; hydraulic elevators, cranes, pile-jetting apparatus, etc., the Crest Meter is recommended. Of the velocity type, a turbine is rotated by the water at a speed directly proportional to rate of flow. Among features is the hollow hard-rubber turbine revolving on agate bearing, resulting in minimum friction, maximum sensitivity, sustained accuracy. Standard Trident register and gear train features. All parts interchangeable.

Trident Crest Meters

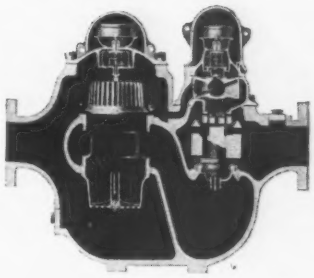
Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	65	12¾	8½	16¼	6⅜	100
1½ Flge.	65	13	8½	16¼	6⅜	100
2 Scr.	83	15½	8⅞	16¾	6⅞	160
2 Flge.	85	17	8⅞	16¾	6⅞	160
3 Flge.	250	24	13⅝	27¼	13¼	350
4 Flge.	260	24	13⅝	27¼	13¼	600
6 Flge.	300	24	14⅝	28¾	14⅜	1400
8 Flge.	500	26¾	17½	30¼	15¾	2500
10 Flge.	800	30	26¾	29¼	13⅞	3800
12 Flge.	1200	36	30½	34⅛	16½	5800
16 Flge.	1950	42	36½	40⅞	19¾	11500

Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications



COMPOUND METERS FOR WIDE WORKING RANGES

Use this Compound Meter for services with a maximum demand beyond the range of equivalent disc meters—yet with the probability of occasional small rates of flow. Accurate over a wide working range. Measures high rates of flow through a Trident Crest Meter unit and small flows, which cannot be recorded accurately by the Crest, through a Trident Disc Meter unit. In addition to the standard Trident features of both these meters, a specially constructed valve automatically directs the water to the proper unit, depending on rate of flow. Single cast iron casing. All parts interchangeable.



Trident Compound Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	460	33	13¾	27⅛	13¼	320
4	475	33	13¾	27⅛	13¼	500
6	685	36½	14⅞	28 5/16	14⅜	1000
8	970	42	17½	29⅞	15¾	1600
10	1500	45 7/16	20 5/16	29⅛	13⅞	2300

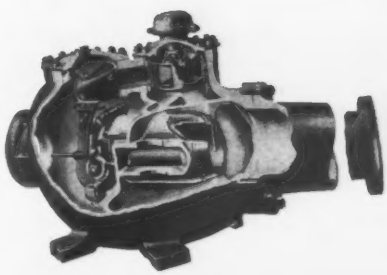
PROTECTUS METERS FOR FIRE SERVICE LINES

Designed for fire line use where both high and low flows occur, and loss of head is an important factor. Meets such requirements with (a) accuracy on all flows and (b) low loss of head plus reliability of operation, satisfying both Water Works officials and Underwriters. Measures low flows through a Trident Disc Meter unit. Large flows are measured proportionally by a Trident Crest unit. Water-way is clear, unobstructed. Both units have standard Trident features which insure accuracy, long life and low maintenance cost.

Trident Protectus Meters

Size In's	Wt. Lbs.	Lgth. In's Incl. Incr.	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	700	64⅜	22¾	21½	8	400
4	900	67	24	24⅞	8	700
6	1600	83⅞	29	27½	10	1600
8	2250	89¾	32¾	30⅞	11¾	2800
10	3400	98⅛	38½	37⅜	14⅜	4400

Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications



NEPTUNE METER COMPANY
New York 20, N. Y.

See Page R-194 for Branch Offices and Factories

Plastic Pipe in Distribution Systems*

A Symposium

Uses and Performance

by RICHARD KING

Prof. of Civ. Eng., Georgia Institute of Technology, Atlanta, Ga.

Plastic materials have become increasingly commonplace in our way of life, and there is a growing interest in the use of plastic pipe for underground water lines. This relatively new material in the water supply field has aroused the interest of engineers and water utility operators, and considerable study and research are currently being conducted to determine its applications in water transmission. The problem of rising costs plagues every industry, and most certainly the water industry is no exception. To reduce these costs a continuous, selective search is being carried on to find more inexpensive and efficient equipment and materials. Because it has a number of desirable characteristics, plastic pipe is being extensively studied, and used on trial bases, to determine its applications to the specific needs of the water industry.

In 1931 polyvinyl chloride compounds[1] were developed by German scientists who proceeded to put millions of pounds into use, some of it in pipes. With the advent of World War II, and in the period following the war, the scarcity of materials and the high cost of labor focused greater attention upon the possible use of plastics. It was in 1950 that this material really entered the water field, and the plastics industry has grown until now it is a major industry.

In general, plastic pipe has the following advantages over metal pipe:

1. Its resistance to rust, corrosion, and chemical and electrolytic attack
2. Its ease and economy of installation
3. Its light weight, long lengths, and workability
4. Its possible elimination of some fittings
5. It excellent hydraulic characteristics
6. Its minimal collection of solids deposits
7. The low capital investment in equipment required to produce it
8. Its low initial cost, in most instances
9. In other instances, the fact that the higher initial costs are cancelled by the elimination of replacement costs.

Definition

One technical dictionary defines plastic as "a substance that can be melted." This obviously includes many materials. Webster's gives the definition: "A plastic substance, specifically, any of a large group of organic, synthetic, or processed materials that are molded or cast and used for making many articles, and are a substitute for glass. Some are cellulose derivatives, some protein, and many are resins formed by chemical condensation or polymerization. Rubber and similar materials are sometimes included among plastics." This definition covers many substances with various physical and chemical properties. Many plastics are now known by their trade names.

A plastic usually contains from one to eight of the following ingredients:

1. A resin or cellulose derivative as the principal ingredient.
2. Carbon black, used as a coloring or added to prevent possible deleterious effects of light penetrations.
3. A mold lubricant to prevent the plastic from sticking to the mold as the pipe is extruded.
4. A plasticizer to soften, increase the toughness, or otherwise modify the properties of the binder
5. An antioxidant to prevent or retard oxidation
6. Accelerators to aid in the vulcanization of rubber
7. Stabilizers to lower surface tension, or to act as emulsifiers or emulsifying aids
8. Fillers to give strength, body, or other properties to the material.

Available Materials

Materials that are available and have been used both in industry and the water industry are polyethylene, cellulose acetate butyrate, polyvinyl chloride (PVC), and rubber-modified polystyrene.

Commercial pipes are produced in sizes ranging up to 12 in. and in length up to 30 ft, and numerous stock fittings are also available. The materials listed above have been extensively used in industry for the transmission of oil, gas, water, acids, alkalis, salt solutions, alcohols, and many other corrosive chemicals.

Plastic water service lines have been installed from the East Coast to Kansas since World War II. Reports from the West Coast[2] show that the use of plastic pipe for service connections has been under study and many connections have already been installed. Numerous irrigation systems in the West and Southwest have been using plastic pipe. Many swimming-pool builders are currently using plastic tubing. The Navy is spending large sums on washdown systems to eliminate radioactive fallout contamination in warships. Plastic pipe (high-impact PVC) was selected because of its resistance to fire, corrosion, weathering, and because of its flexibility.

Reports from some early installations indicate complete suitability for the job and a considerable saving in cost. Others report complete failure and list causes such as rupture, brit-

*Reprinted with permission from *JAWWA* Vol. 50, No. 11, p. 1438 (1958).

tleness, shrinking, and the imparting of taste and odors to the water. Studies have indicated that failures were caused by a lack of engineering understanding of the materials used. Available data indicate that many of these failures are traceable to a lack of satisfactory engineering design or to poor installation techniques. With increased knowledge of plastics and with better controls by the industry to produce a more uniform product, many recent installations are giving satisfactory performance and at considerable savings.

Los Angeles[3] has used plastic pipe on an experimental basis since 1951. Thorough tests have been made with polyethylene and cellulose acetate butyrate tubings, and they are considered unsatisfactory. Attention in Los Angeles has centered on rigid, polyvinyl chloride tubing. Pilot installations have been made in 1-in. size and are being used with pressures ranging from 45 to 150 psi. The current procedure for jointing the tubing is to use a common type of reaming tool to provide an inside chamber on the female end of the pipe, and an outside chamber on the male end of the pipe to be joined to it. The end of the pipe to be belled is heated by a soft flame from a butane torch or a plumber's torch until it becomes soft. Meanwhile, liquid plastic solvent is applied to the end of the cold piece of pipe. Then the ends are butted together and pressure applied. The chambered ends center the tubing and the cold end becomes the forming tool. The unheated pipe is inserted, without the use of any spreading tool, to a depth of 2 in. As the joint cools, contraction and the solvent forms a tight joint. This operation takes less than a minute. Long-radius bends for risers to meters are made by inserting a flexible, metal conduit in the pipe to provide interior support and prevent collapse or buckling. Then the pipe is heated throughout the length of the bend using a butane torch, and in one movement the bend is made. The flexible tubing is then removed immediately. Skilled workmen may perform this operation in about a minute. Repairs to damaged service connections are made by covering the damaged section with a sleeve. The sleeve is softened by heating and slipped over the damaged section, which has been covered with a solvent cement. The repair sleeve is held in place for a few seconds to allow the solvent to weld it to the pipe.

Los Angeles reports considerable savings in the cost of installing polyvinyl chloride tubing as compared to copper tubing, but also recommends certain precautionary measures:

1. Because plastic tubing cannot be located by conventional electronic pipe locators, accurate records are necessary.

2. If plastic pipe is used for house connections as well as utility service connections, some problems of electrical grounding may be encountered, depending upon soil conditions.

3. Bends should be made only after heating to secure permanent set without strain.

The Los Angeles Department of Water and Power reports that it has not adopted plastic tubing for universal use, but that it is expected that experience will lead to its wider use.

The manufacturers of plastic pipe make the following claims regarding its characteristics: It weighs approximately one-fourth as much as steel pipe, is resistant to corrosion and aging, will not support combustion, has good insulating properties, is resistant to abrasion, imparts no taste or odors to the water, and has a low installation cost.

These claims are substantiated by industries that have used this material extensively, but these industries, together with the producers, also recommend that the following things be considered both in design and installation to insure adequate performance:

1. This material has a high coefficient of expansion and temperature variations should be considered. Expansion joints, return bends, or snaking the pipe in the trench is recommended.

2. The tensile strength of plastic is materially affected by temperature and the manufacturers' recommendations should be followed regarding allowable temperatures and pressures.

3. The manufacturers' recommendations as to "effective tensile strength" should be used to prevent failure by creep.

4. Proper bedding should be provided.

5. Proper backfilling procedures should be observed to prevent damage to pipe during installation.

Tests

Because of the natural caution of public health officials in permitting the use of new and untried materials for conveying public drinking water, a study of the suitability of plastic pipe for potable water supplies has been conducted by the national Sanitation Foundation[4]. This foundation has its headquarters at the University of Michigan and is a nonprofit, noncommercial organization. This study was sponsored by the plastics industry with an advisory committee consisting of one representative from AWWA, five members representing state departments of public health, and five members representing manufacturers. These studies were carried on for 3 years using 22 samples of plastic pipe, including polyethylene, cellulose acetate butyrate, polyvinyl chloride, and polystyrene. The purpose of the study was to determine the suitability of these materials for underground use in conducting cold potable water. A partial summary of the report indicates the following:

1. Samples of plastic pipe exposed to natural weathering for a period of a year under standardized conditions showed only slight changes.

2. Burying samples in acid soil of pH 2.0 and holding them at 35°C for a year, with intermittent wetting and drying, showed very little effect on any of the test plastics.

3. Plastic pipe that was partially immersed in test water for a year at 35°C showed only slight color change, slight film formation, and in some cases a slight fungus growth.

4. Extraction tests showed that it was impossible to extract any deleterious substances from test samples that were recommended for domestic water use.

5. Taste and odor studies showed no greater intensity of odors in any of the water samples that had been exposed to plastic pipe than in the controls.

6. In determining the effect of plastic pipe on chlorine residuals, it was found that in no instance was the reduction in free chlorine residual so rapid as to materially change the effectiveness of the chlorination of drinking water.

7. Tests showed that plastic pipe can be satisfactorily disinfected by following standard disinfection procedures.

8. Rats given water that had been in prolonged contact with plastic pipes showed no appreciable abnormal effects as compared to the control group.

9. Plastic pipe was susceptible to rodent attack when the pipe obstructed access to food. There was no evidence that rats ate the plastic or gnawed it in preference to other materials.

Conclusions

Because of certain physical characteristics of plastic pipe as well as its low cost, whereas the cost of metal pipe is always rising, plastic tubing is now being considered more favorably. It is recognized that although price is not the sole index of suitability, it must certainly be considered. Through improved production techniques, plastic pipe is now being produced under better controls, and there is now more standardization of dimensions and closer tolerances. More important, however, is the accumulation of knowledge of the characteristics, applications, and limitations of the material. Although plastics will never completely replace copper, iron, steel, or aluminum, they are no longer the mere substitutes they once were. It has been predicted that plastic pipe will soon capture 15 per cent of the metal pipe market. Plastics have a long way to go before they are completely accepted, but they are well on their way and there can be no doubt that they are here to stay.

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Progress Report

by BERT S. MONTELL

Thermoplastics Pipe Div., Society of the Plastics Industry, Inc., New York, N. Y.

Although the general public considers plastic a new piping material, plastic pipe was actually produced as early as 1940, when it was used in the chemical and food-processing industries.

It was in 1941 that the Southern California Gas Company of Los Angeles initially installed butyrate pipe as distribution lines for natural gas in the metropolitan area of the city of Los Angeles. Since that time many thousands of feet of plastic pipe have been used by the utilities in service lines for the distribution of natural gas.

A survey of 30 distribution companies reveals that they plan to use approximately 800,000 ft of plastic pipe for operational installations during 1958. It is anticipated that a 35 per cent increase in the use of plastic pipe for natural-gas distribution will be attained during this year.

During the past decade, since the introduction of polyethylene plastic pipe in 1948, an increasing amount of plastic pipe is being used in various types of water services, including jet wells, well-to-house piping, lawn-sprinkler systems, service lines, and in varied irrigational services.

It has been estimated that 1,500,000 separately owned water installations in the United States are using various types of plastic pipe. Its successful use for these diversified applications is convincing testimony that plastic pipe is a practical reality today and will give satisfactory service when installed on an engineering basis in accordance with the manufacturer's recommendations and operated within its pressure-temperature limitations.

In recent years there has also been a marked growth in the use of plastic pipe in the petroleum industry. The problem of corrosion resistance in transporting crude oil to distribution centers or refineries is one that has always plagued petroleum engineers. Recognizing that plastic pipe had excellent corrosion resistance as well as physical properties that lower paraffin buildup, the oil companies have continued to use increasing amounts of these piping materials during the past several years.

With a severe corrosion problem to deal with, the mining industry has also turned to plastic pipe because of its high resistance to acids and alkalis. No galvanic or electrolytic action is encountered with plastic pipe, which makes it suitable for use in corrosive soil and water conditions.

The chemical industry, realizing the advantage of the corrosion resistance inherent in the plastic pipe, continues to turn to this product for high-hazard, specialized applications in transporting corrosive fluids. At the present time, however, approximately 75 per cent of the plastic pipe produced is used for conveying water (irrigation, sprinkling, and jet pumps).

Of the various types of plastic materials used in the manufacture of pipe, the principal raw materials are polyethylene (low, medium, and high density), cellulose acetate butyrate, polyvinyl chloride (PVC), and acrylonitrile-butadiene-styrene (ABS).

Polyethylene

Polyethylene material was first extruded into plastic pipe in 1948. The material itself is a derivative of ethylene gas, which is a component of natural gas. It may also be derived from petroleum during refining. The gas is solidified when put under pressures that exceed 20,000 psi.

Polyethylene has an interesting war record. It was originally developed in Great Britain on an experimental basis in 1940. Because the material has remarkable electrical properties, it was used in the construction of radar sets which were used to detect German planes flying across the English Channel. Owing to the superiority of British radar, which in turn depended upon polyethylene materials, the British anti-aircraft was most effective in turning back the Luftwaffe and turning the tide of the Battle of Britain.

Everyone is familiar with polyethylene in housewares and squeeze bottles. Within the past several years a high-density polyethylene material manufactured by a catalytic process has been developed and is now being used satisfactorily in the manufacture of a semi-flexible plastic pipe for various uses.

Although at one time polyethylene

materials were all very similar, this is certainly no longer the case. With new polymerization techniques, polyethylene is made by both high- and low-pressure processes with a sp gr of 0.915-0.965. These materials vary from flexible to rigid, and have short-time tensile strengths of 1,200-4,000 psi.

At first, polyethylene pipe was rated by assuming a factor of safety, usually four, based on short-time burst. As a result of extensive testing by raw-material manufacturers, pipe extruders, and the Society of the Plastics Industry-sponsored Battelle Memorial Institute project, some of the pipes are now rated on the basis of creep rupture data rather than the previous basis. In practice, with compounds especially formulated for pipe, this has resulted in higher permissible fiber stresses with no sacrifice in service performance.

Certain pipe manufacturers are also extruding plastic pipe from a blend of low-density and high-density polyelthylene materials. The flexible polyethylene pipe produced from the low-density or conventional materials is the pipe that still represents approximately 75 per cent of the total dollar market, however. This black flexible pipe is available in lengths ranging from 400-ft coils in the ½-in. size to 200-ft coils in the 2-in. size. It has high impact strength and is the lowest in cost of all types of plastic pipe, in addition to providing the greatest ease of installation. It is limited to relatively low pressure and an operating-temperature range of —65°F to +120°F. Because of its cold-flow characteristics and chemical inertness, it can neither be threaded nor solvent welded. The common method of joining flexible polyethylene pipe is with insert fittings and stainless-steel clamps.

Butyrate

Cellulose acetate butyrate is made of cellulose, acetic acid, and butyric acid. These ingredients are put together to make a plastic. Common uses of butyrate materials are color telephones and automobile steering wheels. Butyrate pipe is black, glossy, and semirigid. It has an operating-temperature range of —40°F to +140°F. Its principal uses have been in crude-oil-gathering lines, salt-water disposal lines, and in new and replacement natural gas service lines. One of its major advantages is its high resistance to paraffin buildup when used in petroleum lines. This pipe is generally joined by solvent welding with slip-sleeve fittings. At present butyrate pipe is not recommended for conveying potable water, as it may impart taste and odor.

Acrylonitrile-Butadiene-Styrene

Acrylonitrile, a colorless liquid, is one of the ingredients used in producing buna-type synthetic rubber. Butadiene and styrene are also used in producing certain types of synthetic rubber. These materials are derived from petroleum. Acrylonitrile, butadiene, and styrene, in combination, make a plastic that has numerous excellent chemical and physical characteristics. It is often made into camera and typewriter cases, as well as various types of luggage. Acrylonitrile-butadiene-styrene (ABS) pipe is noted for its heat stability, toughness, high impact strength and good chemical resistance. It is a relatively rigid pipe, furnished in either blue-gray or black, and has an operating temperature range of —40°F to +170°F. Its principal uses are in the chemical and food-processing industries, as gas transmission pipe to irrigation pumps, and in an increasing number of potable water and irrigation applications. It may be joined by either the conventional threaded connection or solvent welding with slip-sleeve fittings.

Polyvinyl Chloride

Polyvinyl chloride materials may be produced from acetylene. Acetylene gas can be manufactured by treating calcium carbide electrolytically. Today, however, owing to the demand, this gas, and in turn, these materials, are made from petroleum.

These materials are extensively used as insulation on wire, where, to a large extent, they have supplanted natural rubber. In sheet form, they are made into hoods and ducts for use in industrial and chemical ventilating systems where corrosion is a constant problem.

Polyvinyl chloride (PVC) pipe is very rigid, gray in color, and has an operating temperature range of —40° to +160°F. Its principal uses follow those of butyrate and ABS pipe, but it is most widely used in the chemical and food-processing industries. PVC pipe has one of the highest tensile strengths among the thermoplastic pipes. It is known for its good dimensional stability and its outstanding weathering properties. The German chemical industry has been using PVC pipe for over 20 years in places where corrosion is a problem. At the present time, increasing quantities of light-weight PVC pipe are being used on the West Coast, particularly in cold-water distribution services and in irrigation.

All of these classes of plastic pipe are available in iron-pipe sizes in the various schedules. Some of these classes are also available in solvent-welded-pipe (SWP) sizes. Some of the extruders in the industry adopted these SWP sizes to insure that this pipe would be joined by solvent welding rather than threading.

When the plastic-pipe industry started to expand after World War II, the manufacturers recognized the need for an organization. They moved to establish the Thermoplastics Pipe Division within the framework of the Society of the Plastic Industry, Inc. (SPI), which serves as the technical and trade association for the plastics industry. Initially, the pipe and fittings manufacturers undertook to establish dimensional and, ultimately, performance standards on each major class of plastic pipe. They began cooperative research to develop suitable test methods, and established an effective liaison with other associations representing users and potential consumers of plastic pipe.

The Thermoplastics Pipe Division has since established a coordinated relationship with such organizations as AWWA, the American Gas Association, the American Petroleum Institute, the American Society of Sanitary Engineering, ASA, ASTM, and various interested plumbing organizations throughout the country.

Dairy farmers in the Middle West were among the first to use plastic pipe. They were followed closely by many rural and suburban communities, and, as the pipe came to be used extensively in rural and suburban areas, the public health officials concerned with the water supply in these areas gave their attention to the new material. They raised the question of whether any independent research

laboratory had evaluated the suitability of plastic pipe for drinking-water service. Although the companies that supply basic plastics materials knew that their materials were suitable for such service, no research had, in fact, been undertaken by an independent laboratory. At the suggestion of public health officials, the thermoplastic-pipe manufacturers were encouraged to foster a research project to determine the suitability of their product for transportation of potable water. As the National Sanitation Foundation, which is affiliated with the School of Public Health at the University of Michigan, had conducted much research related to this subject, at the instigation of the public health officials, a research project was initiated at the National Sanitation Foundation by the Thermoplastics Pipe Division. This research was inaugurated in 1951 and concluded in 1955. These tests clearly demonstrated that proper formulated plastics, meeting the requirements established by the National Sanitation Foundation, were entirely suitable for use in drinking-water services. Today, the National Sanitation Foundation authorizes the use of its seal on plastic pipe intended for water service when such pipe meets certain rigid requirements. The seal of the National Sanitation Foundation on plastic pipe is the consumers' assurance that the pipe meets the rigid requirements for drinking-water services.

Standards

As the plastic-pipe industry has grown, the need for standards has become increasingly apparent. Programs were initiated several years ago to establish standards. Some standards have already been established. A dimensional standard on polyethylene pipe was first established in 1954 under the procedures of the Commodity Standards Division of the US Dept. of Commerce. Later, this standard was amended to incorporate performance requirements. It was republished in 1957. It is known as Commercial Standard 197-57. During 1957, dimensional standards were established on SWP butyrate and iron-pipe standard PVC pipe. These dimensional standards are known as CS206-57 and CS207-57, respectively. At present, the Thermoplastics Pipe Division is completing the development of material and performance requirements to be included in the polyvinyl chloride pipe standard. Meanwhile, a dimensional and performance standard on ABS pipe is being prepared by division members for eventual establishment as a US Dept. of Commerce standard. Simultaneously, all these standards are being processed through the ASTM and ASA for eventual establishment by those agencies as official American standards.

As a further demonstration of the foresight of the plastic-pipe and fittings manufacturers, a 4-year test research program was undertaken at Battelle Memorial Institute, Columbus, Ohio. This program is now going forward. The goal of this research project is to develop additional test methods that a plastic pipe manufacturer may use for measuring the service performance of the pipe he produces.

The subject of codes is undoubtedly of interest to most water utility men. As most of the plumbing codes were adopted years ago, they make provision only for the traditional types of pipe. It has been necessary, therefore, for the industry to give counsel to code-making authorities at the state and municipal levels in various parts of the country on how the codes should be modified to make provision for plastic pipe where it may be used appropriately.

Considerable research is being devoted to the development of new plastic materials. With the commercial production of these materials, the plastic-pipe manufacturers will test them, and, if they are found suitable, will adopt them as piping materials. Increasingly wide acceptance of plastic pipe in states and municipalities throughout the country, indicates a plastic pipe market of $75,000,000 at consumer level by 1960.

AWWA recently approved the formation of a committee within its organization to deal specifically with plastic-pipe matters. The plastic pipe industry hopes to be able to coordinate its standards activities with this AWWA committee with a view toward eventually promulgating AWWA standards on plastic pipe for conveying potable water.

Butterfly Valve Design and Application*

by HENRY C. SCHWENK

Valve Sales Mgr., Henry Pratt Company, Chicago, Ill.

The butterfly valve has been used since ancient times as a practical device for the control of fluids. In modern usage, it has passed from the use of light-weight dampers for control, to the use of metal seat valves in which the disc is wedged at an angle to the body in an effort to minimize leakage. This development was followed by the disc arm pivot valve method which assisted in obtaining tight shutoff in metal seat valves, and, finally, by the present high-quality rubber seat butterfly valves which can be obtained to AWWA specifications from five to six different manufacturers.

A great deal of information concerning the design of butterfly valves has been published in recent years. The valve manufacturers have expended much time and energy on technical literature designed to provide industry with background material and up-to-date design information. The AWWA has, as is well known, approved two excellent specifications[1, 2] designed to guide the water works industry in the selection of butterfly valves for common applications.

An explanation of some butterfly valve design considerations is extremely helpful in understanding this valve type, in applying it properly, and in specifying it wisely. Several theoretical concepts are involved, and a sound knowledge of them can lead to important savings in applying the butterfly valve to a water-handling problem. Although butterfly valves are basically a simple device, their nature makes them subject to forces not common to most other valve types. It is important, therefore, to discuss briefly the characteristics of the butterfly valve (specifically, the rubber-seated type which has recently come into popular use in certain applications within the water works industry) and the effect of flow conditions on it.

The question of the forces subsumed in line or flow conditions and their effect on valve construction is the aspect of butterfly valve selection most puzzling to the prospective valve buyer, who wonders why he cannot simply specify a 25-psi valve when that is the maximum pressure he expects to encounter. An investigation of the influence on valve design of these forces should explain the apparent anomaly.

The basis for considering line dynamics when using butterfly valves is the fact that the butterfly is not a balanced valve. An unrestrained butterfly valve disc under flowing conditions will go to the closed position. This is an elementary fact, and is true regardless of the direction of flow with respect to valve orientation. This tendency to close under flow conditions gives a clue to the nature of the flow torque and to a means for calculating it. Flow torque, or fluidynamic torque as it is called, can best be explained by likening it to the "lift" experienced by an airplane wing exposed to an airstream. The lift on the wing is due to an unequal pressure distribution on the wing surfaces caused by uneven flow patterns around the airfoil section. On an airplane wing and on a valve disc, the lines of flow tend to take the easiest path around the obstruction, giving rise to the unbalance in force. On a butterfly valve disc, the center of this unbalance occurs at some fixed distance from the shaft centerline. This force, multiplied by its distance from the centerline, equals the fluidynamic torque. The magnitude of this force and, hence, the magnitude of the torque, is dependent on a mathematical relationship between the valve diameter, flow velocity, angle of the valve disc, and pressure distribution across the valve. Its peak usually occurs between disc angles of 30 deg and 80 deg. Equations developed from experimental flow data enable the prediction of this torque quite accurately.

The other special forces bearing consideration in rubber-seated butterfly valve design are seating torque, bearing friction torque, and hydrostatic unbalance torque.

Seating torque, as its name indicates, is the torque required to rotate the valve disc into the rubber seat. Its magnitude depends only on valve diameter and the seat material, and is a constant for any particular valve design.

Bearing friction torque is the frictional resistance to rotation imposed on the valve shaft by the bearings and shaft seal. It is a function of the pressure differential across the valve, multiplied by a constant for any particular valve. This constant, in turn, depends on valve diameter, shaft diameter, and the frictional coefficient between the valve shaft and bearings.

Hydrostatic unbalance torque exists only when a large valve in water service is mounted in a horizontal pipeline with its shaft horizontal. This torque is the result of the hydraulic gradient from top to bottom of a full pipeline, producing an off-center action on the valve disc, with resultant unbalanced torque. This unbalance, while easily determined, is a special case and need not be considered in this discussion.

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The torques just discussed do not occur haphazardly in the operating cycle, but have certain fixed relationships with disc position and pressure differential across the valve. Fluidynamic torque, for example, varies with the angle of the valve disc and with pressure drop across the valve. Bearing friction torque varies with the pressure differential. Seating torque is a fixed value for any given valve size and occurs only in the closed position.

In approaching any given valve problem, a detailed knowledge of actual operating conditions must first be acquired. The values of the dynamic, bearing friction, and seating torques are then calculated. It is easy to see that the dynamic torque occurs only when the valve is off its seat, opening or closing, or at a control point, and that there is bearing friction to be overcome at this time because of upstream pressure against the valve disc. Similarly, it is evident that as the valve is being seated, the line pressure against an almost closed disc (which presents the full disc area for the pressure to work on) will produce a maximum value of bearing friction torque which is added to the seating torque.

After the dynamic torque is calculated the bearing friction torque is computed at the angle at which dynamic maximum is occurring. Addition of these values gives the first torque maximum, which can be designated *Ta*.

Adding the seating torque and the bearing friction torque at closing gives a second torque maximum, *Tb*. The larger of the two (*Ta* or *Tb*) is then the value which is used to establish an operator size. Most leading manufacturers have made this torque-computing job easier for their sales personnel and customers by putting it in tabular form, by using a special slide rule, or by standardizing it by furnishing only "safe" operator sizes. The latter course is the one adopted in the AWWA specification[1, 2] with its use of the minimum torque values as outlined in the torque tables of those specifications.

This brief outline of the effect of line conditions on butterfly design and operator selection should help make clearer the reasons why each butterfly valve application should be analyzed completely before a recommendation can be made. Each such recommendation involves experimentally validated technical experience and a thorough knowledge of the application. The valve manufacturer can supply the experience, but complete information about the application can come only from the engineer or purchaser.

Those who have dealt with or investigated the use of rubber-seated butterfly valves, know that the AWWA has set up three pressure categories for the valves and, within each category, two velocity limitations. The six resulting valve classes are labeled 25-8, 25-16, 50-8, 50-16, 125-8, and 125-16.

The first number in the designation is the pressure rating in pounds per square inch, and the second, the velocity rating in feet per second. These classes were arbitrarily set up with the thought that they would cover the majority of water works applications and, if used properly, protect the user in insuring that he had the proper valve for the job. The pressure-velocity method of rating uses the methods just discussed—that is, it is a way of relating valve design to a set of maximum flow conditions for that class of equipment. This means, for example, that a 25-8 class valve is designed for shutoff at 25 psi and operation at 25 psi with pipeline valve is designed for shutoff at 25 psi level. This does not mean that 8 fps is a maximum velocity but, rather, that the pressure and velocity are together a parameter in this given design. If, therefore, the maximum pressure level is 15 psi, the velocity handled can be in the vicinity of 10 or 12 fps. This point is often confusing to the prospective valve user, and it has been the author's experience that many believe that an AWWA butterfly valve should not be used in velocities greater than 16 fps.

At the present time there are rubber-seated butterfly valve installations operating at velocities up to 40 fps. These valves, essentially AWWA types, are being used without exceeding conventional machine design safety factors. It is recommended, however, that, because of the possibility of cavitation such an application, the installation under consideration be discussed with reputable manufacturers in the industry.

Conclusion

The rubber-seated butterfly valve has been in use in water service in the power field since 1926. It is the author's expectation that it will yet assume a position where it can assist the gate valve, sluice gate, plug, ball, and cone valve in doing a good job for the water works industry.

References

1. Tentative Standard Specifications for Rubber-seated Butterfly Valves—AWWA C504-55T. Am. Wtr. Wks. Assn., New York; *Jour. AWWA*, **46**:943 (Sep. 1954).
2. Tentative Standard Specifications for Metal-seated Butterfly Valves—AWWA C505-55T. Am. Wtr. Wks. Assn., New York; *Jour. AWWA*, **48**:201 (Feb. 1956).

BUTTERFLY VALVE FACT FILE

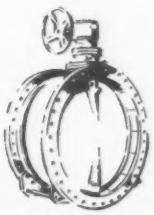
Where to use Butterfly Valves

The field of use for rubber seat butterfly valves is broad, comprising the handling of large volumes of liquid or gas at pressures up to 125 psi. and at temperatures from —20°F to 190°F. Within this area, inherent simplicity of form and function in the butterfly valve give it great advantages over other types of valves.

Henry Pratt butterfly valves are light in weight, compact and mechanically simple, factors that greatly reduce the kind of installation and maintenance costs that can be shockingly expensive in valves weighing a ton or more.

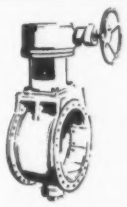
As you can see below, the great advantages inherent in butterfly valves have been multiplied, through Henry Pratt engineering, into a wide variety of practical, economical valving for standard operations as well as unusual problems in power and water works systems.

LOW PRESSURE valves are widely used in water works, power stations and industry where pressures range from vacuum to 50 psi. Pratt has built valves as large as 14 feet in diameter for wind tunnel use, and, for air circulation in nuclear power plants, valves that slam shut in 3/10 of a second.



COMBINATION VALVE AND EXPANSION JOINT combines two functions in one unit. This is economical both in material and installation costs because it eliminates one set of flanges and bolts. Units are built with rubber or steel bellows expansion joints.

HIGH PRESSURE valves are excellent for pump discharge-check applications and water distribution service. These valves have an upper pressure limit of 125 psi and velocity capability as high as 55 feet per second.

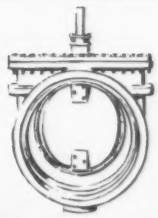


SPECIAL END VALVING. In some installations, such as water main service, flanged connections are not necessary, so both High and Low Pressure Pratt Valves are built with end modifications for bell-and-spigot piping and couplings such as Dresser or Victaulic.

ENDS OF PIPELINES or conduits. Single flange valves can be bolted directly to the end of a pipeline, conduit, settling basin wall or face of a reservoir. Functioning as sluice gates, they have the added advantages of permanent drop-tight shut-off with no need for adjustment or maintenance.

EXTRA LENGTH VALVING. Butterfly valves are often used for economical replacement of other valve types. As Pratt valves are relatively narrow, the laying length is increased by using a wider valve body or adding a spool piece.

LIMITED SPACE. Developed by the Henry Pratt Company, the Ob-Round valve makes it possible to obtain a desired valve area where space limitations prevent the use of a round valve. Ideal for basin or conduit applications.



INSERT VALVING. An original Pratt development that simplifies the replacement of gate valves by butterfly valves. The entire butterfly valve fits inside the gate valve body, saving the cost of removing valve body from the line.

If you would like to know all about Henry Pratt valves, write for our Manual of Rubber Seat Butterfly Valves B-2Q

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RUBBER SEAT Butterfly Valves

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Service Extensions to Fringe Areas*

by THOMAS J. EATON

Supt., Public Service Co. of New Mexico, Santa Fe, N.M.

With an average annual growth in population of 2.5 per cent nationally (in many parts of the Rocky Mountain Section, it is double or triple that rate), water utilities are faced with problems of expansion. The simplest type of expansion arises when a customer enters the office and requests a water service connection to a new home he proposes to build, and the more complex type is when a subdivider brings in a plot showing a group of contiguous sites on which he wishes to construct homes and service buildings suitable to the area.

If the request for new service shows that it is on a street or tract that adjoins a pipeline which has adequate pressure and volume, the problem is solved for the present. The charges for the new connection should be adequate to conform to an overall policy already established. Possible policies are:

1. There is no initial charge, because the rates will cover costs of service and depreciation and there are sufficient capital funds available to make the investment.

2. A nominal charge is made to cover part of the initial capital investment, and the rate will cover costs of service and depreciation. This type of charge prevents unauthorized applications or applications by persons who want water at their lot, but have no intention of building for possibly years to come.

3. A charge is made to cover the complete original cost from the main to and including the meter at the property line.

Basic Concepts

All of these methods or systems of charges for a service line arise from some basic concepts that were laid down by the water utilities at the start of operation, with later modifications (it is hoped) as conditions changed.

A municipal water department usually is brought into being by the demands of a group of citizens protesting failure of wells, or lack of fire protection, or poor service by an existing water utility. The motivating forces determined the initial policy on charges, and it varies widely in purpose. Some may believe that connections at no charge would give encouragement to potential customers and the revenues thus brought in would maintain service thereafter. Another group may have taken over existing utilities which had gone bankrupt due to unexpected high initial costs or high operating costs or failed to be able to render satisfactory service. Historical records in Santa Fe, N. M., for example, reveal the incorporation of about five companies to provide water to its citizens. All faded or were combined into the present Public Service Co. of New Mexico.

Today, the initial service, or installation, charge should be reviewed to bring it up to date in line with the present cost or to reevaluate the original purposes and modify them in line with the objects and policies of the present group of operators. This presents a major problem to a municipal group, as well as to private operators. A municipal department is technically responsible to its owners, the public, through the council and mayor or through a separate board with either appointive or elected members. The will to change may be forced on the department by a deficit in operating funds or the necessity for expansion. It must overcome the tendency toward preserving its present status and proceed with the change. Selling the change may take time, and the change may face severe opposition to the point where a favorable vote is required to increase the indebtedness. Thoroughly complete facts and figures are concrete evidence of the sincere desire on the part of the utility to do a good job. The services of a reputable consultant give added weight to the impartial survey and its ultimate solution. Bearing in mind the fact that the citizens of any community are individuals, it can be forseen that complete agreement with any plan is improbable, and it can only be hoped that the opposition will be reasonable and permit the utility to show that the overall justifiable benefits outweigh the added costs or temporary inconvenience.

A private utility deals with the same public, plus a franchise from the city or town, plus a board of directors, plus a state rate-making body. The private utility has one advantage, however: that once the board has approved a policy, it is not faced with opposition from within. It does face one added hazard: the state commission—but usually its procedure can be carried out in 60-90 days and a final decision secured.

There is one basic distinction between a group of individual service applications and an equal number of the same type of service applications submitted by a subdivider. The subdivider usually requires mains in addition, which increases the capacity of the system to take care of the quantity required. Such strengthening of the system is usually neglected when the additional service is requested by individual customers over a period of time. A different main extension policy is required for fringe area customers, arising from a situation where the subdivider wants water so that he may either build homes himself or sell lots on which others may build. No longer can the utility claim that the former landowner should have put in mains before selling lots so that the original cost could have been equit-

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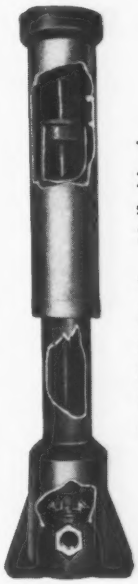

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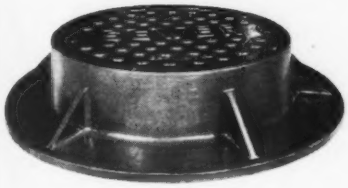

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ably divided by many. Some types of policy must be made known and adhered to.

Fringe Area Policy

The Public Service Co. of New Mexico has adopted the policy of extending mains to fringe areas at the actual cost of the extension required. The applicant deposits in cash an amount equal to the estimated cost of the mains and is refunded a sum equal to 2½ times the annual revenue for each and every service connected to the extension within a period of 5 years. Both parties sign a contract which outlines the legal formalities and defines limits and areas covered by the agreement. One of the simplest statements limits the refunds to a sum not exceeding the total amount deposited. Another statement gives the subdivider credit at the time of making first refunds for any excess of the deposit over the actual cost, or if the reverse is true, the first refunds are credited to extra cost and the balance paid as due.

In these contracts the cost of service from the main to the street side of the property served is not covered. They are controlled by the same base policy as for any individual—a nominal amount of $10 for a ¾-in. or 1-in. service, including the meter and its setting. Actual costs are in excess of $100 per service, including average pavement-cutting costs. Fortunately, most of the streets are narrow and, up to the present time, less than 15 per cent were paved in overall length. Some California utilities reported costs of $171 per service on their generally much wider streets, and where costs had been split $95 to $76, it is now a policy to charge $151 to the customer and $20 to the utility.

On all main extensions, the critical point is the size of the main to be laid. It is clearly seen that if the New Mexico policy of a refund equal to 2½ times the estimated annual revenue is followed and the revenue is $70, the value of the extension can be shown at $175, or about 75 ft. of 4-in. main at an average cost of $2.25 per foot installed. If the main size is 6 in., then at $3.25 per foot, the length is slightly more than 50 ft.

Knowing beforehand what the design for a single customer would require and then having to install a main adequate to serve 50-100 customers and provide fire protection flows in an area not yet built will certainly cause customer protests. The utility can sympathize with them, but only because the customer is realizing for the first time why he was able to purchase the lot or tract at such a comparatively low cost.

The large-scale subdivider goes along with a design as long as he can forsee a 100 per cent return of his contract sum. He protests that it costs him to borrow money to put up for the extension (the individual neglects that cost), and the subdivider wants to put up a promissory note (at no interest) or a bond. The company's answer is that it must pay the material and labor costs at once, and it earns no money until there are customers to whom it can render a bill for service received. The subdivider may say that the utility can borrow the money through its facilities at a low rate and, therefore, it should just add the basic mortgage rate it pays to his costs. On the other hand, the utility cannot serve as agents for the bank; the subdivider must borrow his own money where he can and keep his own books. Often, the utility must present facts about the costs of maintaining the water service and repairs, not omitting the fact that it pays taxes on the added valuation during the initial period when revenues are relatively low.

Expansion of Services

Discussion of fringe area service is restricted in this article to the area covered by the limits of the franchised service area established by the municipality or water district. A broader problem is presented by the service extension requests from outside such an area where consideration must be given to the change of basic policy. Why should service be rendered to anyone not participating in all the costs of operation? Should the rates be different due to added lengths of mains, pumps, and storage facilities required? How much will added taxes, cost of meter reading, and enforcement of water regulations have to do with the rate base? Naturally, these areas contribute much in business and taxes to the community of which they are not directly a part. On the basis of that fact, the utility is often asked to broaden its outlook and become more metropolitan and progressive in outlook.

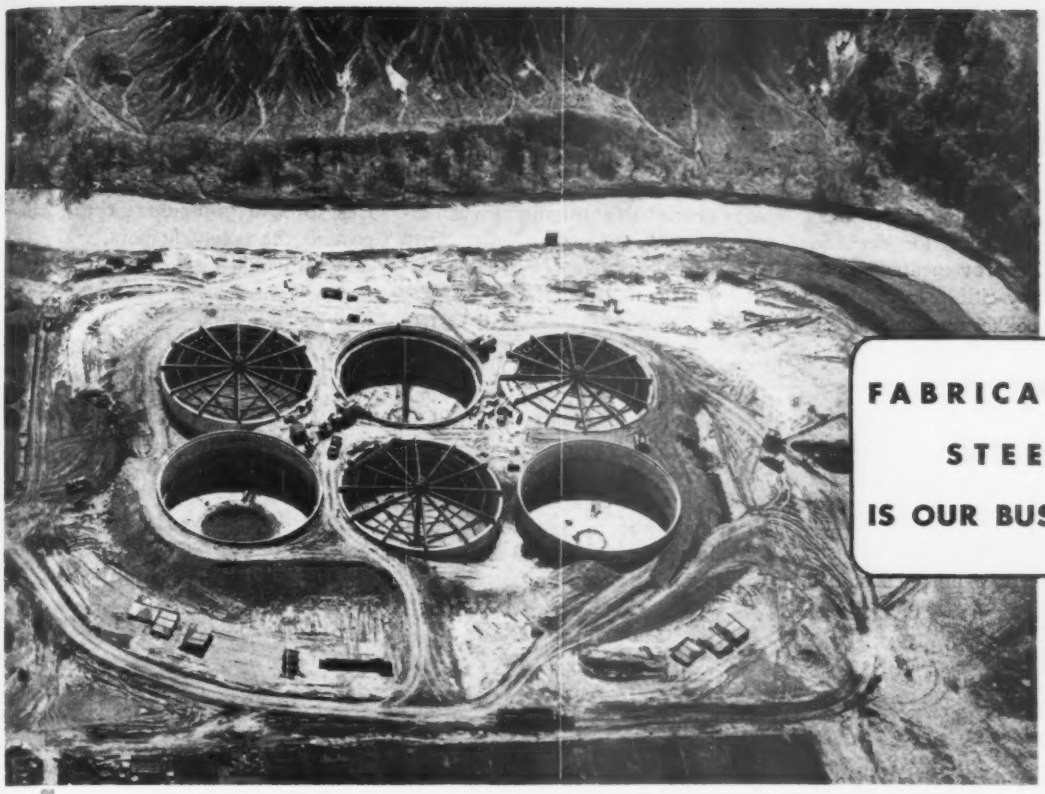
Most growing communities of a small size are faced with the problem of slowly increasing revenues from tax sources and rapidly increasing demands for new and improved municipal services. The tendency is, therefore, to expand and annex piecemeal the parts known as fringe areas over a period of time, and then to repeat the process. Using the water utility as a club by means of increased rates for that purpose alone is wrong. A cooperative study by a group composed of both parties interested in the water utility extension is greatly to be desired. The program should be developed by them to the point where it is ready for sponsoring to the community and the fringe area in its final form. It must be fair to both and almost surely will contain compromises that have been agreed to by both. It is here that controversy arises from the extremists, but ultimately the moderates should prevail.

Fringe area expansion also brings up the fundamental fact that costs of main extensions and resulting revenues are affected by the density of population. Within municipal limits there are undeveloped areas being held for profit, and it certainly costs less for the water utility and the municipality to develop the tax base. Improving density within present areas promotes efficient operations for both.

Problems of Revenue

Control of population density may be vested in a city planning commission, which allocates land usage by means of zoning. They are usually optimistic and set up large areas for acre lots and hold down the areas for commercial and industrial usage. The water utility will get its higher usage in the latter zones, but unless lawn and gardens are installed on the acre lots, the revenue will be below average per mile of main and will adversely affect income.

One of the most recent revenue analyses made in Michigan shows that in 37 systems serving over 10,000 population, the investment averaged $9 per dollar of annual sales, and in the cities serving a smaller population the average investment was $15 per dollar of sales. In New Mexico the ratio is $6.70 per dollar of sales for the Santa Fe Water Division, which has an investment of $4,000,000 and revenues of $600,000. The revenues include all taxes, which are not in-



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cluded in the municipal ratios stated above.

These ratios indicate that proportionally the capital turnover is very low in relation to other businesses in a community, with the consequence that after paying on outstanding indebtedness and for operating costs, the amount remaining for depreciation or capital improvements is almost nothing in many cities. In a municipality, if a bookkeeping surplus appears, it is generally transferred to the general funds, and no capital surplus is available for additions or expansion. It is then necessary to arrange for the sale of bonds of a type compatible with the state and local regulations governing such financing. The arrangement is sometimes costly both in time and money consumed, especially in the present period of high interest rates. Frequently the financial consultants advise that the revenues are inadequate to support the new financing unless the rates are increased.

Some communities have held their rates to the barest minimum when increases were proposed. Today, with increased payroll and material costs for ordinary maintenance and operation alone, their troubles are likely to become matters of public concern.

For what the public receives from water utilities, it pays very little, and this is reflected in the wages and standards of most water utility operations. One example is the service rendered, without adequate compensation, for fire protection. Utilities provide storage, oversized mains, fire hydrants and extra pumps, because the fire departments and the association of fire insurance underwriters demand it as a service to the community. No mention is made of the extra costs to the water utility to improve the efficiency of the fire department and to allow the fire insurance agencies to hold premiums at the same cost to the policy holders, while reducing their losses per thousand dollars of insurance in force and therefore making an increased profit. In other businesses, improved efficiencies and added customers are reflected in the pay envelope of the employees, but not in many water utilities, as shown by an AWWA survey[1].

References

1. Staff Report. Survey of Water Utility Employment Conditions, 1954. *Jour. AWWA*, **47**:508 (May 1955).

Calcite in Water Treatment

by THOMAS M. RIDDICK, NORMAN LINDSAY, and ANTONIO TOMASI

respectively, Consulting Engineer and Chemist, and Associate Engineers in Mr. Riddick's firm, New York City.

In water treatment, it is necessary to apply some type of alkaline reagent to practically all supplies, whether from surface or underground sources. The reasons for this necessity fall into two general categories, namely —(1) Instances where it is desired to raise the alkalinity of raw waters (where deficient) to a point sufficiently high to enable effective coagulation; and (2) those where it is necessary to raise alkalinity and pH of finished waters (well or surface) for the purpose of inhibiting corrosion. Before discussing the application of calcite to these problems, a basic review of nature's methods of dissolving alkaline earths is indicated.

Nature's Part in Producing Alkalinity in Water

When precipitation falls on land surfaces, a major portion normally sinks into the ground and travels downward to the water table, which extends to bedrock or to an impervious formation such as clay. The remainder runs off quickly to brooks, streams and rivers, and unless retained by dams or lakes, eventually flows to the sea.

Moisture vapor in the atmosphere collects on dust particles, or air borne mineral salts which form nucleii for raindrops. This moisture is completely saturated with the gases of the atmosphere, which are principally nitrogen (78 per cent), oxygen (21 per cent) and argon, helium, carbon dioxide and others (1 per cent). Thus at an atmospheric temperature of 50°F (extending several hundred feet above grade), the composition of rain water, in terms of dissolved gases (if at equilibrium and at a barometric pressure of 760 mm mercury), is as follows:

	mg/L by weight	*% by volume*
Oxygen	11.2	0.80
Nitrogen	18.0	1.57
Carbon Dioxide	0.6	0.03

The concentration of these gases in water is a function of barometric pressure and the percentage of these gases in the medium through which the water falls, flows or trickles. Whereas the percentage of carbon dioxide in the atmosphere is only 0.03 by volume, the carbon dioxide content of interstitial air in the upper say three foot layer of soil generally amounts to at least one hundred times this value.* This carbon dioxide is an end product of metabolism of micro organisms — including bacteria, yeast, fungi, moulds and actinomycetes. Whereas rain water, per se, has little mineral content as it falls upon land or water surfaces; and whereas its carbon dioxide content is only 0.6 mg/L (by weight), the high concentration of carbon dioxide in the upper soil layers generally results in a pick-up of some 20 to 100 mg/L in transit from the ground surface to the water table. Carbon dioxide combines with water as follows:

(1) $H_2O + CO_2 \rightarrow H_2CO_3$

Mineral compounds and alkaline earths, which constitute the soil, dissolve very slowly in pure distilled water. The rate of solution however is greatly increased by the presence of carbonic acid (H_2CO_3); and within limits, the higher the concentration of carbon dioxide, and the longer the pe-

*Soil Microbiology—Waxman—John Wiley & Sons, Inc.—1952.

RHOMBIC CRYSTALLINE STRUCTURE of limestone from Newton, N. J., is shown by these quarter-inch mesh size particles which occur during crushing operation to produce "flour" used in the employment of . . .

riod of contact between carbonic acid and the mineral contents of the earth the greater will be the dissolved mineral solids in the underground water.

Practically all natural waters, including New York, New Jersey and Connecticut contain calcium and to a lesser extent magnesium bicarbonate due to this action, and all waters contain some excess of carbon dioxide, whether they are derived from running streams or from underground sources. The flow of brooks, streams and rivers is of course maintained during dry seasons of the year by the discharge of underground waters (which are relatively high in carbon dioxide) into stream beds. When this underground seepage becomes open stream flow, carbon dioxide is gradually released to the atmosphere. These conditions and reactions, though elementary, are fundamental to the concept of water treatment.

Since sub-surface waters (such as those drawn from wells or infiltration galleries) have relatively long contact with underground minerals they generally contain a greater quantity of mineral salts than brook waters from the same area. Stream waters vary greatly in concentrations of mineral solids throughout the year, whereas well waters are relatively constant; and if stream waters are collected in a reservoir, the concentration of mineral solids from the reservoir overflow (or point of withdrawal) is naturally more constant than that obtained from the streams feeding such reservoirs.

The Hackensack River at Nyack, N. Y. will vary in alkalinity from about 30 to 80 mg/L, and this moderately high alkalinity is due to the incidence of relatively large quantities of alkaline earths (principally limestone and sandstone) on the watershed. At Ossining, N. Y. the alkalinity of the raw reservoir water will vary from 14 to 18 mg/L during any year. The lower concentration at Ossining is due to relatively less calcareous rock (or soil) on the watershed. No generalization can be made with regard to watersheds, however, even those in close proximity. At Bethel, Conn., for instance, the alkalinity of Chestnut Ridge Reservoir Water varies only from 7 to 10 mg/L, whereas that of Eureka Reservoir, situated only a few miles away, varies from 20 to 30 mg/L.

Alum Coagulation Reactions

At most water works treating surface waters, aluminum sulfate is applied to form a gelatinous precipitate —which adsorbs color, iron and manganese and absorbs or immeshes turbidity. The reaction is highly complex, but for purposes of general discussion may be set forth as follows:

$$(2)\qquad \underset{600}{Al_2(SO_4)_3} + \underset{300}{3Ca(HCO_3)_2} \rightarrow \underset{156}{3CaSO_4} + \underset{264}{2Al(OH)_3} + 6CO_2$$

The pure crystalline form of aluminum sulfate has eighteen molecules of water of crystallization, and a molecular weight of 666. The commercial form of alum employed for water works contains approximately 14.2 molecules of water and has a molecular weight approximating 600. Since alkalinity is always measured in terms of equivalent $CaCO_3$ we find the following relationships in Equation 2: 1 mg/L of aluminum sulfate requires 0.5 ppm of calcium bicarbonate (as equivalent calcium carbonate); and upon reacting, produces 0.68 mg/L of calcium sulfate (which remains in solution); 0.26 mg/L of aluminum hydrate (a gelatinous floc which mainly settles out in the sedimentation basin); and 0.44 mg/L of carbon dioxide.

From these considerations it is stoichiometrically necessary to have at least one-half as many mg/L of calcium bicarbonate as the application of alum (in mg/L). Since alum dosages are normally 15 to 40 mg/L, 30 mg/L of alum requires 15 mg/L of natural (bicarbonate) alkalinity. The law of "mass action" states that the rate of reaction is proportional to the molecular concentration of each of the reacting substances. The above reaction therefore does not go to completion (within the time normally available) unless there is an excess of about 5 mg/L of bicarbonate alkalinity. Thus an alum dosage of 30 mg/L requires at least 20 mg/L of alkaline bicarbonate.

Thus when raw water alkalinities are less than about 20 mg/L, it is generally necessary to add some type of alkali to augment this deficiency. Of the commercial alkalies available, soda ash and lime are the most commonly employed. Of these, the cost of soda ash (based on current prices and alkalinity equivalents) is about three times the cost of lime. Both lime (a hydrate) and soda ash (a carbonate) have distinct limitations—regardless of cost and of rate of application, since we need raw water alkalinity in the *bicarbonate* rather than the carbonate or hydrate form. When lime is applied to raw water before coagulation, it has the tendency to raise pH to a point so high that the normal alum dosage will not lower the pH of the treated water to a point where adequate or effective floc is formed. It also inhibits the adsorptive properties of floc so that color is often inadequately removed. In common parlance, high dosages of primary lime are said to "set the color".

Ossining, N. Y. Experience

For many years the Ossining raw water was very difficult to treat. Color removal was poor if primary lime was applied, for reasons above stated. Since the raw water alkalinity always ranged 14 to 18 mg/L, this limited alum dosage to about 20 mg/L, which was barely sufficient to produce a heavy-bodied quick-setting floc with good color adsorptive properties. Treated water on top of the filters was very low or virtually devoid of alkalinity (1 to 5 mg/L), thereby risking the passage of alum through the filters. The application of secondary lime to raise pH and alkalinity of the finished water to inhibit corrosion, formerly resulted in pH values of 8.6 to 8.8 being attained with a resultant alkalinity of the finished water of only 12-20 mg/L. pH values in excess of 8.8 impart a rather "flat" taste to the water, which is objectionable in this section of the country, and the alkalinity of 12-20 mg/L was too low to inhibit corrosion in spite of the relatively high pH.

Thus from the standpoints of coagulation and corrosion control the problem at the Ossining plant has always been that of inability to apply a greater amount of alkaline calcium salts, without objectionably raising pH. In other words, the need has been for a greater amount of calcium bicarbonate, and the difficulty was how to supply this without unduly raising pH.

Another separate and distinct operating difficulty at Ossining has been that of taste and odor. About ten years ago "superchlorination" was instituted, and this treatment was main-

tained for several months. Though results were generally gratifying, several periods of intense taste and odor (probably augmented by this type of treatment) necessitated abandoning this procedure. Thereafter the "excess chlorine" type of treatment was instituted; it consisted of the addition of several mg/L of chlorine in excess of superchlorination requirements. Normal chlorine applications prior to superchlorination were about 2 mg/L, and during the period of superchlorination these were increased to 4 to 5 mg/L.

The excess chlorination treatment at Ossining has required dosages of 8 to 12 mg/L, and the rate of application is governed by the free chlorine residual of the filter effluent. This must be from 2.0 to 3.0 mg/L. It is then necessary to dechlorinate (SO_2 is employed) to residuals of 0.3 to 0.5 mg/L, otherwise severe taste and odor difficulties are experienced on the distribution system.

It has been found by experience that the excess chlorine treatment will: (1) bleach color in the raw water from values of 30-40 to 5-10 mg/L; (2) substantially eliminate all taste and odor if sufficient aeration is effected to remove the nitrogen trichloride and other biproducts; and (3) oxidize iron and maganese to insoluble precipitates which are removed by the filters. The Ossining plant has operated continuously over the past nine years with the excess chlorination treatment, supplemented by alum coagulation about 40 per cent of the time when this was required for greater color removal.

Effect of Chlorination on Alkalinity

The application of 8-12 mg/L of chlorine introduced another distinct problem as far as alkalinity is concerned. The chemical reactions involved are as follows:

$$\overset{70}{Cl_2} + \overset{18}{H_2O} \rightarrow \overset{36}{HCl} + HOCl \quad (3)$$

$$HOCl \rightarrow H^+ + OCl^- \quad (4)$$

$$\overset{72}{2HCCl} + \overset{100}{Ca(HCO_3)_2} \rightarrow CaCl_2 + \overset{88}{2H_2O} + 2CO_2 \quad (5)$$

From these equations, it is evident that: 1 mg/L of applied chlorine forms 0.51 mg/L of hydrochloric acid, which requires 0.71 mg/L of bicarbonate alkalinity (as equivalent $CaCO_3$) for neutralization. Thus the application of 10 mg/L of primary chlorine reduces the alkalinity of raw water 7 mg/L and adds 0.63 mg/L of carbon dioxide. During periods when high dosages of primary chlorine were applied, the alkalinity of the Ossining finished water was so low that the application of secondary lime, though resulting in a pH of 8.6 to 8.8 still left a deficiency in alkalinity from the standpoint of corrosion control. In order to effectively control corrosion the alkalinity of the finished water should be at least 30 mg/L and preferably 35 to 40 mg/L. This conclusion has been verified repeatedly in corrosion studies of the Ossining and similar waters. Values below 15-20 mg/L generally results in "red water" on the distribution system regardless of pH—even if sodium silicate is also applied as a corrosion inhibitant.

In summary additional calcium bicarbonate was badly needed to improve flocculation, to provide the alkalinity depleted by excess chlorination, and to maintain sufficient alkalinity in the plant effluent to inhibit corrosion on the distribution system.

Methods of Increasing Alkalinity

There are a number of ways in which lime can be converted into calcium bicarbonate, and naturally all require carbon dioxide. Some of the methods considered or tried at Ossining are as follows:

1)—A lime feeder could have been installed at the head waters of one of the brooks feeding the reservoir. This would have raised alkalinity and pH of the brook water, and ultimately the reservoir water. The pH would have gradually decreased during the several months of storage due to adsorption of CO_2 at the water surface from the atmosphere. This application, though practical, could not be effected since the stream bed would have been covered with lime deposits thereby impairing its esthetic value to adjacent property owners.

2)—A lime suspension could be continuously aerated (by means of carborundum diffuser tubes) in a large open basin. Atmospheric carbon dioxide would have then convert the hydrate into carbonate—and ultimately into bicarbonate form. The cost of the required amount of air under pressure was prohibitive, also the time of detention was too long for practical usage.

3)—Carbon dioxide gas could be bubbled under pressure through a milk of lime solution (or suspension), thereby quickly converting the calcium hydrate into calcium bicarbonate. The cost of carbon dioxide in either the gaseous or solid form was rather prohibitive.

4)—Several years ago, about fifteen tons of lime were piled in furrows on the reservoir ice cap during the winter months. When the ice cap melted, the lime came into intimate contact with the reservoir water, and it is probable that a good portion of the lime dissolved before reaching the muck bottom of the reservoir. This raised alkalinity of the entire reservoir water about 12 mg/L, and continuous exposure of the water surface to atmospheric carbon dioxide enabled an increase in alkalinity without objectionably high pH. This operation was therefore successful, although the alkalinity naturally diminished to normal during the next three or four months due to dilution by runoff. Summertime application could have been made by applying lime with a power boat; however, since lime is relatively insoluble, it would have to be applied in the dry powder form. Besides being difficult, this is hazardous as lime is a painful eye irritant.

None of these or other conventional methods for increasing bicarbonate alkalinity seemed sufficiently promising for routine procedure.

About twelve years ago, finely ground Calcite was applied to the raw water preceding the point of alum application in an attempt to raise alkalinity with a carbonate. Since Calcite is relatively insoluble in water, only a small portion went into solution, with the bulk dropping out at the inlet end of the sedimentation basins. The slight increase in alkalinity was insufficient to maintain desirable alkaline levels either in water on top of the filters or in the plant effluent after the addition of lime.

The overall problem was next approached along lines of preventing or diminishing depletion of the natural bicarbonate alkalinity by alum and chlorine. This approach ultimately

led to a much better solution than would have resulted from merely being able to raise the calcium bicarbonate content of the raw water.

Calcite Characteristics

Calcite is primarily calcium carbonate, which is the principal constituent of limestone. Whereas there are innumerable outcrops of limestone in this country and throughout the world, they vary greatly both in terms of calcium and/or magnesium carbonate, and in terms of percentage of extraneous minerals such as silica. A high calcium, low magnesium, low insoluble content limestone, is preferred in the manufacture of lime for waterworks use. This preference is due to the relatively low solubility of calcium carbonate, which enables the formation of a protective pipe coating. Magnesium carbonate, although alkalinity, is too soluble to form such coatings. Limestone deposits may be essentially calcareous or essentially dolomitic, with many inbetween gradations. Some limestones, such as marble, are relatively soft and dissolve readily in acids. Others, such as Iceland Spar (a very pure calcium carbonate), dissolve slowly in strong acids even when heat is applied.

The limestone outcrop near Newton, N. J., is highly calcareous and highly crystalline, with relatively low silica and other insolubles. From these quarries, Limestone Products Co. of Newton produces lime for industrial and water works use, and ground Calcite in many sizes for uses varying from roof coatings to poultry feed. Their finest size of ground Calcite now marketed as "Aqua-treat" is air-separated, with about 95 per cent passing a 325 mesh seive. Up to the present time this material has been used principally as an industrial filler. In terms of hardness and solubility in acids it lies about midway between soft marble and Iceland Spar. It was believed that this product might be employed by premixing with dissolved alum in concentrated solution, provided the reaction was limited and controlled.

Alum Floc Composition

It is well known that floc formed by the reaction of alum and natural waters is an exceedingly complex compound. Pure aluminum hydroxide floc has an isoelectric point, or pH of minimum solubility, lying in a rather narrow and low range as was demonstrated by Thierault and Clark* in 1923. Their conclusions were ". . . when other possible factors are left out of consideration . . . optimum conditions for floc formation will be found with a narrow zone of pH centered for dilute solution at pH 5.5".

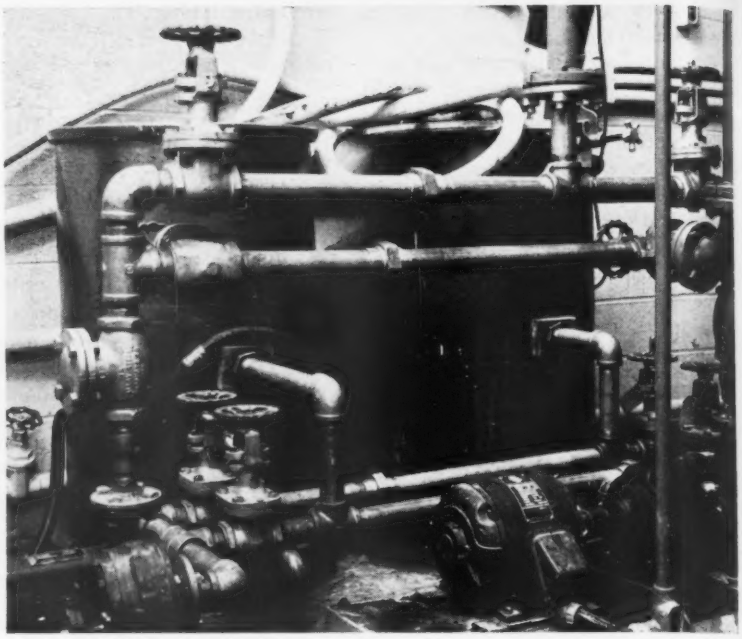
Two years later Lewis P. Miller,** dealing with flocculation involving calcium and magnesium carbonates and sulfates (and other dissolved and suspended matter) noted the decided difference between pure aluminum hydroxide, and the floc normally formed by the reaction of alum with natural water. He refers to ". . . that complex substance commonly called alum floc and often incorrectly termed aluminum hydroxide". Miller correctly concluded that "1)—there must be added a certain minimum quantity of aluminum ion; 2)—there must be present an anion of strong coagulating power such as the sulfate ion; 3)—the hydrion concentration must be properly adjusted."

The sulfate and other ions of natural raws waters decidedly influence the pH at which full bodied, highly adsorptive, and tough floc can be produced. At Ossining for instance the pH of the treated water following the application of alum must be in the range of 5.6 to 6.6 for effective coagulation.

The conventional application of alum depresses pH of natural waters in two ways, (1)—by lowering the natural alkalinity, and (2)—by forming carbon dioxide which itself suppresses pH. If alum is applied to raw waters before aeration the carbon dioxide formed is largely eliminated by this process—resulting in a higher pH than is normal if alum is applied following aeration. In the latter instance most of the carbon dioxide formed (say 5 to 15 mg/L) will remain in solution during passage of the treated water through the sedimentation basins and filters. Since the pH range for optimum coagulation is fairly narrow—generally from 0.5 to 1.0 unit of pH in the range of pH 5.6 to 7.0, it follows therefore that alum dosages must be governed to a large extent by this condition rather than dosages being proportioned in accordance with the amount of color, iron and other constituents which must be removed in the treatment process.

Floc Formation

If sufficient lime, soda ash or other



CHEMICAL MIXING CROCKS receive discharge from alum and Calcite dry feeders and the primary chlorinator. After a limited reaction period of 30 to 60 seconds, the solution-suspension is pumped to the raw water either before or after aeration.

*U.S. PHS. Reprint No. 813
**U.S. PHS. Reprint No. 992 and 1028

alkali is added to say a ten per cent solution of commercial alum, copious floc is immediately formed due to the mass action occasioned by these high concentrations. If this floc is then discharged into raw water at a rate equal to a dosage of say 30 to 40 mg/L (of commercial alum), little or no adsorptive power is evidenced, and more often the floc will be broken up, and remain in a highly dispersed or peptized state—which would result in poor settling and large amounts passing the filters.

Floc formation is a highly complex mechanism and probably involves first the agglomeration of jelly-like masses of microscopic or ultra-microscopic size building around physical particles such as silt or algae. From the outset this build-up is heavily influenced by the electrical charge of the cations and anions inherent to the original nucleus, the flocculating agents per se, and the electrical charges characterizing the dissolved and/or suspended mineral or organic matter contained in the raw water.

The presence of a starting nucleus is evinced by the difficulty often encountered in coagulating very clear waters almost devoid of turbidity and the great improvement often noted by the addition of a few parts per million of clays such as Bentonite. As the minute floc particles grow to larger sizes—first to the microscopic and then to the macroscopic stage, there must be a continual adsorption of color colloids and of course iron, if it is also present in the raw water.

The role of sulfates in this primary building stage is rather vague—but sulfates are a part of the complex substance collectively termed floc. The build-up of these microscopic particles into larger units is principally for the purpose of producing a relatively large discrete particle having good settling characteristics (on account of size) and having characteristics of toughness which will result in these flocculant masses being retained at or near the surface of a filter, rather than penetrating or passing through the sand. The build-up of pin-point size particles to those pin-headed in size (and larger) is of course a function of the number of particles which collide or coalesce while in the mixing basin.

Calcite—Alum Reaction

It was believed that the Newton Calcite, being relatively insoluble, might be successfully combined with a strong solution of alum, provided that the time of detention was so limited as to prevent the reaction from going through to completion, and further provided that mechanical agitation during this reaction was sufficient to prevent the microscopicly sized floc particles from coalescing and agglomerating into large masses. It was also believed that the chlorine solution from the chlorinator, due to the mass action of the strong solution would also react with the Calcite to form a type of hypochlorous acid or alkaline hypochlorite. The reaction of aluminum sulfate and Calcite is as follows:

$$(6)\quad \overset{600}{Al_2(SO_4)_3} + \overset{300}{3CaCO_3} + 3H_2O = 3CaSO_4 + \overset{156}{2Al(OH)_3} + \overset{132}{3CO_2}$$

Thus 1 mg/L of commercial alum would require 0.5 mg/L of Calcite, forming 0.26 mg/L of aluminum hydrates and 0.22 mg/L of carbon dioxide. If the three molecules of carbon dioxide combine with excess Calcite instead of being evolved as a gas, then 1 mg/L of aluminum sulfate could react with 1.0 mg/L of Calcite —forming as end products calcium sulfate, aluminum hydrate and calcium bicarbonate.

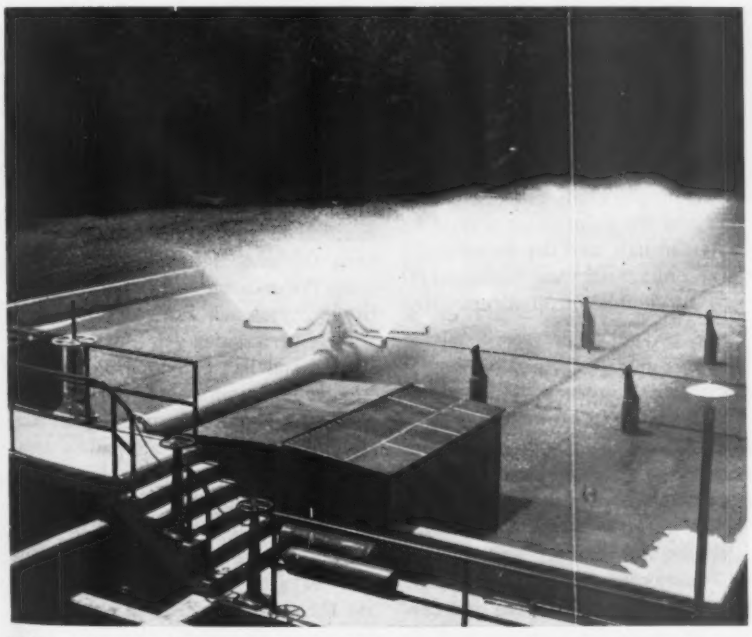
The reaction of chlorine with Calcite would be:

$$(7)\quad \overset{140}{2Cl_2} + 2H_2O + \overset{100}{CaCo_3} = CaCl_2 + H_2O - \overset{44}{CO_2} + 2H^+ + 2OCl^-$$

In the above reaction 1 mg/L of chlorine would therefore require 0.71 mg/L of Calcite, with the formation of 0.31 mg/L of carbon dioxide. If the CO_2 formed by this reaction also reacted with excess Calcite, then 1 mg/L of chlorine would react with 1.42 mg/L of Calcite and raise alkalinity in the amount of 0.71 mg/L for each mg/L of chlorine added. This reaction would be as follows:

$$(8)\quad \overset{44}{CO_2} + H_2O + \overset{100}{CaCO_3} = Ca(HCO_3)_2$$

The Ossining Plant (constructed about thirty years ago) is poorly designed by contemporary standards. There is no formal mixing basin other than an aeration tank 100 ft long and 50 ft wide which receives the spray from primary aerators—and which also has a 100 ft length of submerged carborundum tubes for additional aeration. Although the detention in this basin approximates more than two hours which is more than ample (or desirable) for floc formation, the high



TASTE AND ODOR is controlled by high pressure aeration plus Aqua Nuchar. Calcite coagulation also reduces taste and odor by greater precipitation of algae and decaying organisms.

velocity of upwelling currents induced by the submerged aerators tends to break floc and prevent its build-up. The Ossining plant is therefore poorly adapted to a tryout involving a controlled reaction of alum and Calcite, or chlorine and Calcite; and this type of treatment, involving continuous flow as well as controlled reaction, could not be readily duplicated in a laboratory set-up. Since the Oneonta, N. Y., water works was then in the design stage in our office however, it as felt that a Calcite installation at Ossining would at least provide sufficient data for proper design of the flocculation facilities of the Oneonta Plant.

Experiments at Ossining

The discharge line from the Ossining chlorinator was therefore disconnected from the raw water inlet line, and connected to the solution pot of the dry chemical feed machine handling Calcite. The strong chlorine water reacted sufficiently with the Calcite to substantially neutralize the hydrochloric acid formed by the reaction of chlorine with water. The rate of Calcite feed was set sufficiently high to provide for reaction with the chlorine and also to leave sufficient excess to react with the normal alum dosage required for the 2 mgd of raw water flow. The discharge lines from the Calcite machine and from the alum feeder were then run to a crock in the basement—which was fitted with an agitator. After a detention period of thirty to sixty seconds the resultant solution was pumped to the raw water line before aeration.

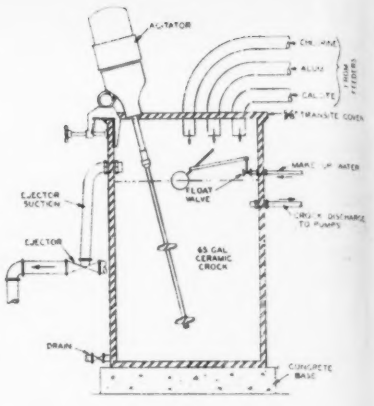
In spite of the crude type of flocculation basin — designed essentially for aeration—floc formation and sedimentation showed considerable improvement over that normal to the conventional treatment of simply applying alum to the raw water line and relying upon natural bicarbonate alkalinity for floc formation.

Results Applied to Oneonta Plant Design

These operating results, though highly qualitative, were considered sufficiently promising to serve as a basis for design of all chemical feed and flocculating units of the Oneonta Plant.

The Oneonta Water Works has a raw water very similar in character to that at Ossining. Alkalinity is in the range of 13 to 16 mg/L, which definitely requires some type of primary alkali for the 20 to 30 mg/L of alum necessary for satisfactory floc formation and color removal. At Oneonta the discharge of the alum and Calcite machines are run by gravity to a sixty gallon crock located in the basement. (See accompanying photograph and sketch). This crock also receives the hose line from the chlorinator, and has a fairly tight asbestos-cement cover. In order to remove the slight chlorine vapors created within the crock (and which would be acute in the event that the Calcite feeder would through mechanical failure be put out of service), an Uscolite ejector was installed with suction connected to the top of the crock to remove chlorine vapors as formed. An agitator is installed in the crock to mix the three chemicals, to prevent the excess Calcite from dropping out and to prevent the floc from growing to more than microscopic sie. After a suitable detention period in the crock, ths solution or mixture is then pumped either to the raw water line before aeration or to the aerator flume preceding the flocculation basin. This of course constitutes a controlled chemical reaction, and as with most reactions, this is a function of concentration of chemicals and time. Discharging say 10 gpm each from the alum and calcite crocks and 20 gpm from the chlorinator, the detention in a 40-60 gallon crock should be in the range of 30 to 60 seconds with a solution (water) temperature of around 70°F. In the coldest months of the year with temperatures in the range of 35-40 the discharge from the alum and calcite dry feeders and the chlorinator should be cut about in half, and the detention in the crock increased from about 40-60 gallons to double or quadruple this value.

Operating experience shows that there is some tendency of the alum-calcite-chlorine mixture to form a coating in the 2-in. pipelines from the pump handling this mixture. Spectrographic analysis shows aluminum to be the major element with iron, silicon and titanium being minor. In still lower concentrations the sludge contains magnesium, sodium and calcium. Although the sludge can readily be removed by recirculating a 10 per cent inhibited hydrochloric acid



— CHEMICAL MIXING CROCK —

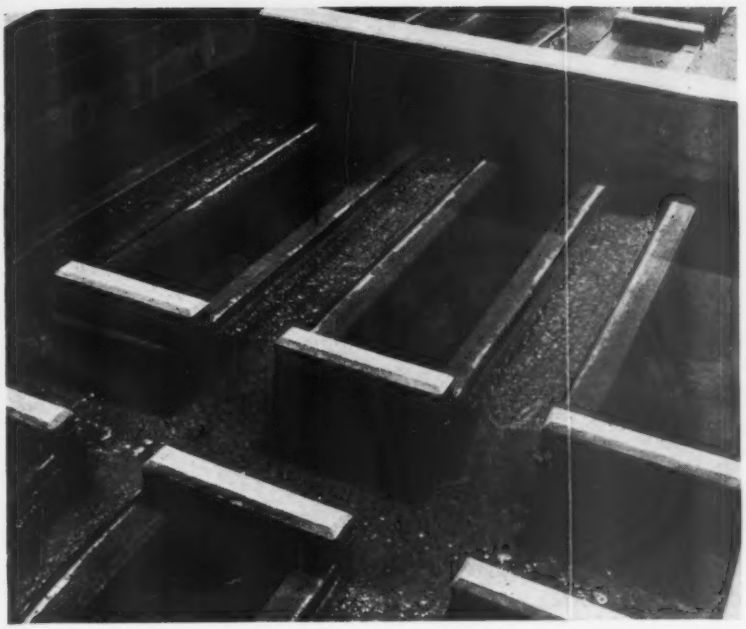
CROSS-SECTION shows design of chemical mixing crocks.

solution, a preferable overall arrangement (if hydraulics permit) is to locate the discharge from the chemical feeders above the flow line in the plant so as to permit gravity discharge to the raw water. The chemical feed lines should have as short a run as possible to permit occasional manual cleaning with a wire brush similar to the type employed for boiler tubes. The mixing crock and agitator should then be located outside the control building. This also has the advantage of permitting the slight chlorine volatilized to escape to open air.

The aeration flume extends the width of all three sedimentation basins and is 4 ft 6 in. wide and 3 ft in water depth. A 4¼ in. O.D. line of carborundum tubes is located the length of this flume and the forced aeration provides sufficient agitation to prevent the undissolved Calcite from dropping out and prevent the microscopically sized floc from further build-up.

The flume discharges into three flocculation basins, which form the head ends of the sedimentation basins. Each flocculation basin is divided into three bays, each 7 ft long by 19 ft wide, with a water depth of 11 ft 6 in. Each basin has two longitudinal Jeffrey type agitators. There are four paddle arms and four paddles on each agitator in the bay, four paddle arms and three paddles in the second bay, and three paddle arms and three paddles in the third day. This provides a tapering degree of agitation in the three bays, and multiple sprockets permit the flocculators to be operated at tangential speeds of 0.8, 1.0 or 1.2 ft per min.

There is a lapse of two to four min-



SIX PLASTIC WEIRS at effluent end of sedimentation basins assure a low velocity of approach, thereby increasing the efficiency of sedimentation in basins where the bottom in 11.5 ft of water can be clearly seen when operating at the design rate.

utes (at a treatment rate of 4.5 mgd for which the plant was designed, in accordance with New York State Health Dept. Requirements) between the application of alum to the raw water and its entrance to the first bay of the flocculation basins. Up to this point floc formation of appreciable size has been intentionally prevented by agitation in the crock, through the aerators, and through the aerated mixing flume. Upon entrance into the first bay of the flocculation basins the floc then seems "ready and willing" to form. The dosage of Calcite is such as to leave a residual after reacting in the mixing crock, and examinations with a stereoscopic microscope indicate a general reduction in particle size from 325 mesh, to particles sized about one-half or one-third their previous diameter. These small sized Calcite particles thereby furnish innumerable nucleii on which discrete particles of floc can form in their build-up. In addition to this they serve as a physical and mechanical weighting agent, and a microscopic examination shows about ten to fifty pin-point sized Calcite particles enmeshed in each discrete particle of floc.

Plant Results at Oneonta

The overall results of this treatment are superior coagulation and a much greater immeshment of the colloidal turbidity (and algae) normally found in reservoir waters. The size of floc is generally somewhat larger than obtained at conventional plants under conventional methods of treatment. However, it has been found that color and colloidal turbidity removal is excellent whether resulting floc particles are moderately small, average or large. Color removal within the ranges encountered at Oneonta (20 to 45 mg/L) is substantially complete. Iron removal is also complete and no difficulty was occasioned by the recent cleaning of the raw water transmission line which resulted in iron concentrations for the first hour of operations each morning of from 0.5 to 5 mg/L.

In the Ossining pilot experiments it was not known whether the Calcite particles immeshed in the floc dissolved after the floc precipitated to the bottom of the sedimentation basin to form sludge. At Oneonta the sedimentation basins are provided with mechanical flight scrapers and blow-offs, which readily enable collecting samples of the precipitated sludge. Our observations show the tiny particles of Calcite immeshed in the floc are still undissolved several weeks after they have settled to the bottom as sludge. It is probable that they would remain undissolved for many months or almost indefinitely. At Oneonta this cannot be readily checked (in situ) as sludge is removed from the basins bi-monthly which of course always maintains them at maximum capacity from the standpoint of sedimentation efficiency.

The limited facilities at Ossining did not permit proper evaluation of the alum Calcite time detention factor or a determination of the optimum ratio of Calcite to alum. Based on twenty years of experience at this plant, and based on general laws governing flocculation, it was felt that both the time element and ratio of Calcite to alum would be critical. Operating experience at Oneonta during the summer months, however, shows little difference between one-half and one-minute of alum-Calcite mixing time and it has been found that a Calcite dosage anywhere in the range of 25 to 75 per cent of the alum dosage is effective in producing better floc. A ratio of about 50 to 75 per cent seem optimum however, since the greater dosages appreciably add more weighting material and result in a quicker subsidence of floc.

Ratio of Calcite to Alum

Naturally the greater the ratio of Calcite to alum, the higher will be the resulting pH of treated water in the flocculation basins. Jar tests of the Oneonta water employing the maximum amount of alum (about 25 mg/L) allowable for the limited natural bicarbonate alkalinity showed optimum floc formation to be in the range of 6.0 to 6.7. It was initially felt therefore that the Calcite dosage (or ratio of Calcite to alum) would have to be limited to that which would enable a comparable pH in the flocculation basins. Operating experience however proved that this is not the case. Floc formation is good to excellent at pH values as high as 7.3 and slightly above. A pH of 7.3 represents an alum dosage in the range of 20-25 mg/L with a ratio of Calcite to alum of 60 to 70 per cent. With the higher ratio, precipitation is markedly aided due of course to the greater number of minute Calcite particles which serve as a weighting agent. Operating experience also indicates that the carbon dioxide formed by the reaction of Calcite with alum, and with chlorine, is principally released to atmosphere at the liquid level of the crock, due un-

doubtedly to its supersaturation in this solution, as well as to the inability of carbon dioxide to react quickly with the relatively insoluble Calcite.

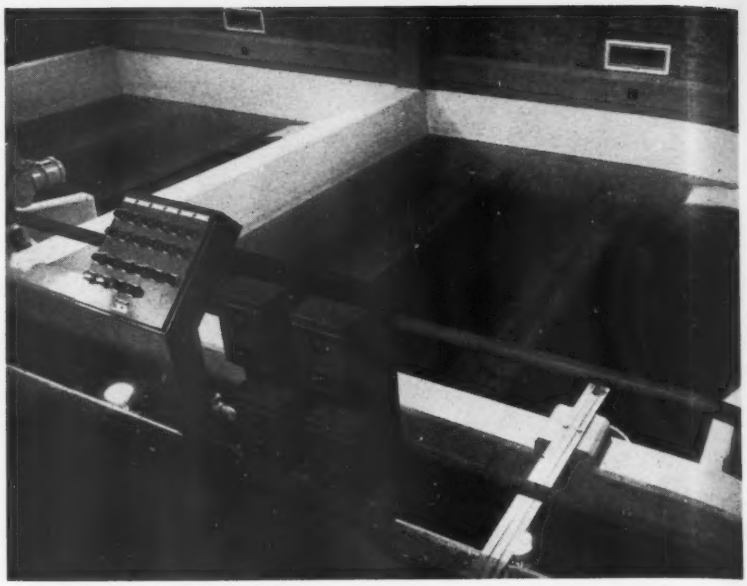
Sludge Behavior

Precipitated sludge from the alum-Calcite process exhibits rather unusual behavior compared with sludge produced by the reaction of alum with natural bicarbonate alkalinity. The blow-off line from the flight scrapers discharges to a drop-inlet manhole with a fall approximating ten feet. Thereafter the sludge passes at high velocity through a corrugated steel line several hundred feet in length before discharge to the brook. Samples of sludge collected after passage through this manhole and pipeline are therefore about as "beaten-up" as is possible. It is interesting to note however that if a two-liter beaker of this sludge is collected, the 7 to 10 per cent solids will completely reagglomerate and settle to the bottom of the beaker within a few minutes time, leaving a clear supernatant. It would seem that ability to reform and clarify so quickly would have to be attributed to favorably charged cations and anions, resulting in considerable forces of attraction.

High Rate Operation at Oneonta

For its first few weeks in service the Oneonta Plant was operated at 4.5 mgd—the design capacity of the plant in accordance with conventional standards. The work at Ossining had been sufficiently indicative, however, to give rise to the hope that this coagulation process might enable a plant to operate at considerably greater than the design rate—hence all flumes, pipe lines, and other limiting hydraulic structures were designed for double the rated capacity, or 9.0 mgd. When the plant was operated at the design rate of 4.5 mgd the clarity of settled water at the effluent end of the sedimentation basins (six full-length weirs per basin were employed to assure very low velocities of approach) was such as to enable the cleaning mechanism located at the bottom to be clearly seen through eleven feet of water.

After about three weeks of operation at normal rate, the plant was stepped up in capacity by throwing in service an additional 2.5 mgd pump. Since the pumps discharge slightly greater than design capacity, the rate of pumping is in the range of 6.8 to 7.0 mgd. Mr. C. M. Taylor, Water Superintendent at Oneonta, has elected to operate at this higher rate since it naturally reduces the daily hours of operation by one-third, or from a twelve- to eight-hour operating day.



CLARITY OF TREATED WATER, due to the virtual elimination of colloids, is such that the water troughs and sand beds in the filters can be seen during operation.

At the higher rate, color, iron and turbidity are reduced to a substantially immeasurable point by Standard Methods procedures. Filter runs are generally in excess of 24 and often in excess of 48 hours. The plant effluent is sparkling clear and has real polish. This is undoubtedly due to rather complete removal of colloids.

Taste and Odor Removed

Taste and odor removal has been excellent. During late August, September and October (1957) the reservoir was drawn down eight or nine feet which represents the height to which the old dam was raised some thirty years ago. This dam raising operation had flooded flat meadow lands, and with a drawdown of eight to nine feet, about one-quarter of the total reservoir water surface has a water depth no greater than about one foot. Needless to say, this water was green with algae and imposed on the plant a rather rigorous load from the standpoint of taste and odor removal. Aeration was relied on heavily to effect this improvement, the spray aerators being operated at a pressure of ten to fifteen psi—resulting in a spray height of about twelve feet. In addition to this about 2 mg/L of activated carbon (Aqua Nuchar) is normally applied.

At one time during a test period, a minor break-down of the Calcite feeder necessitated discontinuation of Calcite and operation with straight alum, employing the natural alkalinity of the water as a source of primary alkali. Floc formation deteriorated materially and the colloidal content of treated water rose to the point where it was no longer possible to see the top of the filter sand or the wash water troughs. A slight though perceptible odor was also detected in the plant effluent although 2 mg/L of carbon was being applied. After two days of outage for repair, the Calcite machine was again placed in service. The colloidal turbidity disappeared and the odor was eliminated.

The relationship between Calcite and odor removal must lie only in the superior coagulation by Calcite and a greater removal of organic suspended solids (algae and decomposing growths of vegetation). This observation is also confirmed by the dosage and residuals of secondary chlorine. Primary chlorine is limited to a dosage sufficient to effect adequate sterilization of the raw water. This normally represents an application of 1.0 to 1.5 mg/L with residual of about 0.2 mg/L in water discharged from

the aerator basin. This dosage must be a great deal less than is required to reach a break point. On the other hand, a dosage of 0.35 mg/L of secondary chlorine results in a chlorine residual very closely approaching this figure—showing that there is very little chlorine demand (at this oxidizing potential) filtered water.

Floc Feed-Back

It should be stated that at the Oneonta Plant another device is employed to aid further, the formation of floc. This is a floc feed-back system which returns about 20 per cent of heavily flocculated water from the effluent end of the third (last) flocculator bay to the entrance end of the first bay. The combined detention through the first three bays amounts to 33 minutes, or 11 minutes per bay at a rate of 4.5 mgd. It is believed that this heavy bodied and aged (33 minute) floc is quite helpful in quickly building moderately heavy floc in the first bay. Air lift enables this return with a minimum break-up of floc particles.

It would seem that the use of the Calcite-alum process—and the flocculation feed-back process—would enable many existing well designed water works to be successfully operated at higher than normal ratings. This is particularly true for plants which have good flocculation facilities. The Calcite-alum process may also have considerable usage in improving the efficiency of sedimentation in upflow clarifier units, many of which have been designed with detention periods which proved too low, or conversely, upflow rates which proved too high. This would seem to be confirmed by the superior performance of upflow clarifiers when operated for lime-soda softening. The weighting of floc with natural Calcite should be quite comparable to weighting with precipitated calcium carbonate.

Ed. Note: Both the Calcite-alum and floc-feed-back processes, as well as many of the authors' statements were so interesting that we requested commentary from Mr. L. L. Hedgepeth, Technical Consultant to American Cyanamid Co. (and Editorial Associate of *Water & Sewage Works*) and Mr. George W. Moore, Chief, Water Supply Section of the New York State Health Dept.

Both the Calcite-alum process and the floc feed-back systems are being patented. The process is quite economical as the cost of Calcite approximates one-half that of lime.

Comments by L. L. Hedgepeth

Mr. Riddick's experience with relating floc formation to *quantity of alkalinity*, in addition to the intensity (pH), is borne out in his practice of coagulation. Many persons have explained the zone of optimum coagulation of alum in natural water as being a pH function, thus setting aside the earlier concepts of coagulation calculations. But Riddick finds that, under his conditions of experimentation, a minimum quantity of alkalinity must be present in order for the flocculation to be clean cut in the optimum pH range. Also it would seem that the presence of undissolved calcite should be helpful in starting the reaction which results in discrete floc particles, and the excess calcite per se may result in a beneficial modification of the essential chemical composition of the floc.

Similarly Riddick's conversion of chlorine water into an aqueous solution of hypochlorite through reaction with calcium carbonate is a new approach to water coagulation, although the reaction itself has been understood and practiced in water chlorination for more than twenty years. A number of chlorine investigators, including the writer, have advanced the idea that a hypochlorite chlorination is different from chlorine water chlorination in that the hypochlorite "oxidizes" where the chlorine water "chlorinates". Others hold that, in the dilutions of chlorine commonly used in water treatment, there is no material difference in the chemical behavior of hypochlorite and chlorine water solutions of equivalent strengths. But the writer's experience has indicated that there is a distinct difference between the two when chlorine is used as a chemical agent. Recent experiences with hypochlorite solutions versus chlorine gas in cyanide oxidation cause the writer to believe that the weight of the evidence favors the hypochlorine as being the most efficient.

Comments by George W. Moore

Calcite (fed separately from alum) has been used effectively in several upflow contact basins in New York State during the past four or five years but no real study has been possible of chemical reaction between Calcite and alum as a coagulant. However, the following physical observation have been made:

(1) The primary advantage of using calcite seems to be its weighting action in keeping slurry and floc from rising in the upflow basins.

(2) Jar tests and plant operating tests indicate that the floc formed when coagulating relatively clear cold water is stronger and will not break-up with a moderate degree of agitation.

(3) Although not established in the plant using Cacite in upflow coagulation, it is quite possible that the Calcite particles are enmeshed in the floc as observed by Mr. Riddick at Oneonta.

In plant operation at Oneonta, the method of applying the coagulant and Calcite in combination with chlorine is unusual. It will be interesting to learn whether or not similar results can be expected if the coagulant, Calcite and chlorine are applied separately as originally done in rapid sand filter plants. Based on experiences showing the effectiveness of the use of Calcite in solids contact basins, it has been my belief that Calcite would be of value in standard coagulation and settling basins.

(4) Coagulation jar tests conducted with water having somewhat the same physical characteristics as the raw water at Ossining and Oneonta but having a somewhat higher alkalinity, indicate that effective coagulation can be secured with a reduction in color and an increase in the size and toughness of the floc, providing the samples are agitated at a velocity sufficiently high to maintain Calcite in suspension. The floc also has excellent settleability due to the weighting action of the Calcite.

In jar tests using Calcite, there does not seem to be a tendency for the color to be set, consequently effective color reduction is secured by the use of Calcite with pH in the coagulated water between 6.9-7.0. Normally the water, when using alum alone, requires a pH of 6.4 to 6.5 for maximum color reduction.

I, for one, look forward to additional information, not only on the Oneonta experience but other plants including upflow contact basins, as well.

The Chemistry of Water Coagulation

by A. P. BLACK

Head, Department of Chemistry, University of Florida, Gainesville, Fla

It is well for those of us who are engaged in any phase of water treatment to occasionally review the basic principles having to do with the processes being employed. These articles are prepared with that in mind. They do not purport to contain any material which is new or original and no references to the literature will be cited. They have been prepared with the idea of briefly summarizing the most important chemical principles underlying certain processes of the chemical treatment of water. Part I will deal with coagulation; Parts II and III with softening and corrosion control, respectively.

Coagulants may be defined as those substances which are capable of removing colloidal impurities from water, and coagulation is the process by which such removal is brought about.

As we look back over what has taken place during the past seventy-five years, it seems rather clear that the development of coagulation as an art was greatly influenced by the development of slow sand filters, the first of which was constructed in 1829 by James Simpson of the Chelsea Water Company, London. Its effectiveness for the purification of water is too well known to require discussion here. It was early noted that its efficiency was greatly improved after the formation on the surface of the sand of a slimy gelatinous coating which was and still is termed "Schmutzdecke." There seems little doubt but that when early American workers began their development of the rapid sand filter it was their desire to duplicate by chemical means this slimy coating or schmutzdecke on the sand.

Since a chemical was to be used, however, it had to possess certain qualifications. It must, first of all, be gelatinous in nature so as to resemble as nearly as possible the organic growths on the older slow sand filters. Furthermore, it must be non-toxic, it must be relatively inexpensive, and it must be capable of reacting either with water itself or with substances naturally present in water or which might be added to water so as to produce the necessary gelatinous precipitate. As we all know, aluminum sulfate or a filter alum was selected for study. Although many years have passed since alum was first used for this purpose, it is probably true to say that it is still the most widely used of all coagulants in water treatment.

It is the purpose of this paper to show that the remarkable properties of filter alum as a coagulant are not due to its gelatinous nature but to entirely different properties unknown to the earlier workers. It is one of the most remarkable coincidences in contemporary science that after the real mechanism of coagulation became known, filter alum still remained the most widely used of its class.

It is possible to write equations for the chemical reactions which take place when aluminum sulfate is added to water containing natural alkalinity or added alkalinity in the form of lime or soda ash. These are show below:

1. $Al_2(SO_4)_3 \times H_2O + 3\ Ca(HCO_3)_2 = 2\ Al(OH)_3 + 3\ CaSO_4 + 6\ CO_2 + (X-6)H_2O$
2. $Al_2(SO_4)_3 + 3\ Ca(OH)_2 = 2\ Al(OH)_3 + 3\ CaSO_4$
3. $Al_2(SO_4)_3 + 3\ Na_2CO_3 + 6\ H_2O = 2\ Al(OH)_3 + 3\ Na_2SO_4 + 3\ CO_2$

While it is probable that there are cases where these reactions take place essentially as they are written, it is also probable that there are many cases where they do not go about it in exactly this manner. In order to understand that statement and the true mechanism of coagulation, it is necessary to examine the nature and properties of colloids.

Colloids, Their Classification and Properties

The colloidal phase refers to any form of matter in a certain state of subdivision or, better, within certain limits of particle size. The unit of measurement to be used is the millimicron or mμ. This is one-millionth (0.000,001) of a millimeter, which is approximately one twenty-five millionth of an inch. While no definite limits may be set within which various phases of matter may be grouped, it is possible to state that the molecules and ions of true solutions usually vary in diameter from 0.1 to 1 mμ. The particles in the colloidal phase will usually fall between 1 mμ and 100 mμ; above the higher figure they merge into the suspensions and emulsions which may be separated more or less readily by physical means.

A solid or particle size between 1 and 100 mμ when dispersed in a liquid is called a suspensoid, and a liquid the droplets of which vary in diameter from 1 to 100 mμ when dispersed in another liquid is called an emulsoid. Both are colloids. In most respects colloids resemble true solutions; in ordinary lighting they are clear and transparent, they will not settle, and they may be filtered without removal of the colloidal material. Under proper lighting conditions, however, a bright beam of light passed through a colloidal solution produces what is called a "Tyndall Cone" which results from the reflection of part of the transmitted light by the tiny particles. Under the ultra-microscope colloidal particles are found to be in constant motion. This motion, termed the "Brownian movement," results from the bombardment of the tiny colloidal particles of the colloid by the rapidly moving molecules of the solvent. The boiling point, freezing point, osmotic pressure and vapor pressure of colloidal solutions are essentially identical with those of the pure solvent.

Colloids may be classified in a number of ways. In the first place, they may be classified as sols or gels. Sols are, of course, colloids which have the appearance of true solutions, whereas gels have a jelly-like structure from which the name colloid (Greek: Like glue) was derived. Sols and gels may be readily demonstrated by anyone by two simple experiments. For the first experiment, one takes two 1-liter beakers, one containing boiling distilled water and the other distilled water just above the freezing point. If to each beaker there is added two or three drops of a saturated solution of ferric chloride a most interesting contrast will be noted. The beaker containing the cold distilled water will exhibit only the very faintest color of the dissolved ferric chloride, hardly perceptible to any except the trained eye; the other beaker, however, assumes a deep wine-red color. The explanation of course is that at the temperature of boiling point the ferric chloride is hydrolized with the formation of colloidal ferric hydroxide and soluble hydrochloric acid. This ferric

hydroxide sol is crystal clear and may be filtered through the finest laboratory filter paper unchanged. If the cold beaker be set aside for a few hours or over night, it will gradually color up until the same wine-red intensity is finally reached. If both are allowed to stand for a few days a reddish gelatinous precipitate of ferric hydroxide will result in each. This is due to the fact that other ions present in the solution will finally cause precipitation. If, however, these colloids are dialized and these foreign ions removed, the colloidal solution will be stable almost indefinitely. The writer has in his possession and has many times shown colloidal solutions of ferric hydroxide, of metallic silver and metallic gold, which are at the present time fifteen years old and which have maintained their strength essentially unchanged during that period.

Another simple experiment may be used to demonstrate the formation of a gel. In one beaker is placed 30 ml. of a clear saturated aqueous solution of calcium acetate. In a second beaker there is measured out 170 ml. of 95% ethyl alcohol. If now the alcohol is rapidly poured into the clear limpid solution of calcium acetate and then an attempt is made to pour the mixture back into the first beaker, it will be found that the mixture has set to a solid gel before the transfer can even be begun. This gel is so stiff that it may be penetrated by the finger only with difficulty, yet it is formed within a matter of moments from two clear free-flowing solutions.

Colloids may be classified as reversible and non-reversible. Ordinary starch solution is an excellent example of the former. If a little starch is added to boiling water and the mixture boiled for a few minutes, a clear, faintly bluish solution results. When allowed to cool it sets to what is termed "starch paste." However, if reheated it will again assume the appearance of a solution. Egg albumin or ordinary egg white is an excellent example of a non-reversible colloid. A small amount of fresh white of egg added to water and thoroughly shaken yields what appears to be a true solution. If now this mixture is boiled the egg white is coagulated and it may not be again transformed to its original state since a permanent change in the material has taken place.

Colloids may be classified as lyophobic and lyophyllic. This classification has to do with the affinity of the colloidal particles for the dispersing medium. If the attraction between the colloidal particles and the dispersing medium is small, the colloid is termed lyophobic. If, on the other hand, the attraction between the colloidal particles and the dispersing medium is great the colloid is termed lyophillic. The viscosity of lyophobic colloids is usually about the same as that of the medium, and they are quite susceptible to coagulation. The viscosity of lyophillic colloids, on the other hand, is usually much greater than that of the pure medium. In water treatment we deal for the most part with lyophobic colloids.

Finally the most important of all, colloids may be classified as positive or negative since it may readily be shown that they bear electrical charges. There are a number of theories as to the source of this electrical charge, but these are beyond the scope of this discussion. It is sufficient for us to know that the particles of some colloids bear a positive charge whereas the particles of other colloids bear a negative charge. It is also true that colloids may be prepared in essentially neutral condition and it is further necessary to note that colloids may change their electrical charge from positive to negative or the reverse as a result of a change or changes in external conditions. The latter point is very important in the theory of coagulation since it has been shown by numerous workers that both aluminum hydroxide and ferric hydroxide flocs may be either positive or negative. This has a most important bearing, not only on floc formation, but also on the completeness with which a coagulant will do the job it is supposed to perform.

Methods of Precipitating Colloids

Colloids may be precipitated in a number of ways. Three will be mentioned since each of these has found applications or plays a part in water treatment.

The first is by electro-phoresis. This rather involved word simply means the precipitation of a colloid of one sign on an electrically charged pole of opposite sign. As a specific example, if we immerse two electrodes in the beaker of ferric hydroxide sol whose preparation was described earlier in the paper and pass a direct current through the sol, the wine-red color may be observed to slowly drift toward the negative electrode and a precipitate of gelatinous ferric hydroxide forms on and below that electrode. Since the colloidal ferric hydroxide particles have moved to the negative pole we may assume that before they were neutralized they bore a positive electrical charge. There are, on the other hand, various colloids which when placed between charged electrodes will move to the positive pole. These, of course, are negative colloids.

It is interesting to remark at this point that the two types of impurities for which coagulation is most commonly employed, namely color and turbidity, are both present in water in the form of negative colloids. This point is emphasized since it is most important in the discussion to follow. During the past few years a number of devices employing this principle of electro-phoresis have been suggested for practical use under various trade names. They have not been particularly successful due to polarization of the electrodes and frequent cleaning which is necessary.

Colloids may be coagulated by other colloids of opposite sign. For example, if to a negatively charged colloidal sol there is added an equivalent quantity of a positively charged sol, something akin to neutralization takes place and a precipitate is formed which consists of the mixture of the two substances originally present. This is most important in connection with coagulation of a water and will be referred to again later.

In the third place, and most important of all, colloids may be precipitated by ions of opposite charge. For example, if to a stabilized ferric hydroxide sol bearing a positive charge a little hydrochloric acid is added, the sol will be precipitated by the negatively charged chloride ion. This is the explanation for the ultimate precipitation of the ferric hydroxide hydrosols whose preparation has been described. There is, however, a very great difference in the relative precipitating power of ions and this power results from the value of the charge carried by the ion. Keeping in mind that in a discussion of this sort, only very general statements can be made, it is possible to say that as a rule the precipitating power of a bivalent ion will be 50-60 times as great as a monovalent ion and the precipitating power of a trivalent ion will be 600-700 times as great as that of a monovalent ion.

It is this remarkable fact which throws most light on the action of soluble aluminum and ferric salts as coagulants in water treatment. It may be demonstrated by dividing a positively charged ferric hydroxide sol prepared as described above into three equal portions. To one there is added a small amount of sodium chloride. To the second is added an equivalent amount of sodium sulfate and to the third is added an equivalent amount of one of the soluble sodium ortho-phosphates. The sodium chloride will have very little effect in precipitating the sol, the effect of the sodium sulfate

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will be very much greater and that of the sodium phosphate greatest of all. If the experiment is carried on in such a manner that quantitative results will be obtained, values for the relative precipitating power of the ions approximating those just given will be obtained.

Having now reviewed some of the chemistry of colloids, we are in a position to examine the known facts of coagulation and to attempt to explain them in terms of the behavior of colloids. We have learned that both color and turbidity present in natural waters are present in the form of negative colloids. That leads us at once to the conclusion that for their coagulation we will need to employ either a positive ion or a positive colloid or both. As it happens both agents take place in the phenomenon of floc formation. We discover now by examining the chemical formulae for filter alum and ferric sulfate or ferric chloride that these coagulants each have a positive ion whose valence is three. Though chemists have carefully searched the periodic table of the elements and have made efforts to employ other elements of the same valence and elements of higher valence, it still remains true that these salts are most effective and most widely used as coagulants.

Mechanism of Coagulation and Floc Formation

When a coagulant is added to water for the removal of color or turbidity three separate factors and three different types of action are involved. They will be discussed in the order in which they take place.

1. As the coagulant dissolves and the trivalent aluminum or ferric ions become available, they neutralize the negative charge on the particles of color or turbidity and, as we have seen, their neutralizing power is very great. This, in the opinion of most authorities, is the most important phase of coagulation and it takes place long before the visible formation of floc particles. It is evident that this action will be more efficient if the coagulant can be brought into intimate contact with the material to be removed before secondary reactions can take place. This clearly implies the desirability of rapid mixing as the first step in coagulation.

2. When the positively charged aluminum or ferric ions have neutralized a considerable portion, perhaps most of the negatively charged colloidal particles of color or turbidity, the resulting particles may be called micro-flocs for the purpose of this discussion since they are still beyond the limits of visibility and far too small to settle under the influence of gravity. Furthermore, it has been shown that, in the acid range of coagulation most commonly employed, they still retain positive charge, possibly due to the adsorption of positively charged hydrogen ions from the solution. We are now dealing, therefore, with a positively charged colloid which has the capacity to neutralize the negatively charged colloid. These positively charged micro-flocs can therefore continue to remove negatively charged particles of color or turbidity, and this constitutes the second phase of coagulation.

3. During both of the above phases no visible floc particles have formed. The mechanical treatment of the water from this point forward should consist of slow stirring, termed by some authors "conditioning" in order that these tiny micro-flocs may cluster together and agglomerate with the formation of floc particles which steadily grow in size until they are in a proper condition for sedimentation. During this phase of floc growth the third action, that of surface adsorption, takes place. It is outside the scope of this paper to deal with the various theories of adsorption, and the complex forces which may be and probably are involved. It is sufficient only to say that the amount of surface area exposed by the innumerable particles of floc is very great and that impurities in the water may be adsorbed on these active surfaces. It should be emphasized however that the formation of a large and well formed floc, while important from the standpoint of sedimentation, is not necessarily the criterion of successful coagulation since the most important functions of the coagulant take place, as has been shown, before the floc ever attains visible size.

Influence of Other Ions Present in Water

It has been stated that the micro-floc particles formed by coagulation with either filter alum or ferric sulfate in the acid range bear a positive charge. This has an important implication to the water chemist since it should mean that a water high in sulfate ion should be coagulated more readily than a water low in sulfate ion or high in chloride ion and that is true. While the precipitating power of the bivalent negative sulfate ion is not as great as of a trivalent ion it is still very high and it is true that sulfate waters are more readily coagulated in the acid range than are chloride waters, and for the same reason ferric or aluminum sulfate are better coagulants than the corresponding chlorides. It follows also that since the ions are charged, each ion present in a given water will have some effect on floc formation, the positive ions in the water interfering with the formation of a positive floc and the negative ions helping in its formation. This is one of the important reasons which explains the individuality of waters as far as their coagulation is concerned. As will be shown in the next paper in this series, the softening of water by any of the known processes follows well defined chemical laws and dosages, and results can be calculated in advance. This is not true with coagulation. The first of the chemical equations which has been listed above presents what would happen if filter alum reacts completely with natural alkalinity present in a water. Assuming for filter alum a "practical" molecular weight of 600, which corresponds to about 14.5 molecules of water of crystallization, one grain per gallon of alum would reduce the alkalinity of a given water by 8.5 parts per million. If pure aluminum sulfate whose formula is $Al_2(SO_4)_3 .18 H_2O$, and whose molecular weight is 666 be used, then the theoretical reduction in alkalinity by one grain of alum is 7.7 parts per million. Every water works operator who is experienced in coagulation is, however, well familiar with the fact that it is possible to add a considerable dosage of alum to a water with alkalinity reduction substantially less than called for by either of these figures. This indicates the correctness of the theories of coagulation which have been set forth above and results from the fact that a considerable fraction of the aluminum ions instead of reacting with the alkalinity of the water react directly with the negatively charged particles of color or turbidity.

In the case of organic color, the flocs formed are called "color flocs" and are quite different in properties and appearance to the gelatinous aluminum hydroxide formed by the reaction of aluminum sulfate with alkalinity in water. Although this is true, it has not been found possible to arrive at equations for calculating the amount, which will hold in every case, for a given coagulant to remove a given amount of color or turbidity from a water. Such equations are published from time to time and are usually valid for the particular water from whose treatment they are derived but as a rule they are found not to hold in case of other waters. This can only mean of course that we do not as yet have sufficient information with regard to the true nature of the

colloidal impurities which we are removing from water. This is particularly true with respect to organic color. After more than fifty years of water treatment, we still find ourselves in the position of using more or less rule-of-thumb methods for the removal from water of a material about whose chemical composition we know relatively little. Much research needs to be done on the fundamental nature of color in water.

Coagulants Used in Water Treatment

It is hardly worthwhile to attempt a complete listing of the coagulants which have been used in water treatment since most water works men are familiar with them and they receive frequent mention in the literature. As has been previously stated, aluminum sulfate continues to be the most widely used material of its kind but there appears to be an increasing tendency toward the use of ferric sulfate. Sodium aluminate often finds application, particularly in industrial water treatment. Ferric chloride and chlorinated copperas have been used and in the Middle West a combination of ferrous sulfate and lime is widely used, mainly for the removal of turbidity. It was one of the first coagulants to be used in this country, having been used by Bull in Quincy, Illinois, in 1898.

The use of Bentonite has been suggested but it has not been generally adopted although it has proved useful in certain cases. The use of activated silica as an accessory coagulant deserves special mention. A solution of sodium silicate, activated with sulfuric acid as recommended by Bayliss, by aluminum sulfate as recommended by Graf and Schworm, or by ammonium sulfate, chlorine, carbon dioxide, and so forth as recommended by Hay and others, yields a stable sol bearing a high negative charge. In the acid range it effectively promotes coagulation and floc formation with either aluminum sulfate or ferric sulfate. It is not generally recognized, however, that activated silica may act as a coagulant in the truest sense of the word since, in softening many waters by the lime-soda process it results in the formation of a better-formed and better-settling sludge than either alum or ferric sulfate. The new 80-million gallon softening plant of the City of Miami is being designed to employ activated silica as the only coagulant although facilities will be provided for feeding alum to anticipate possible changes in water quality. In the case of this particular water a dosage of 2-4 parts per million of activated silica yields better results than a dosage of three grains per gallon of alum. While activated silica used in conjunction with another coagulant should properly be called a coagulant aid, the time has come to recognize that it may and often does act as a coagulant in the truest sense of the word.

Laboratory Control of Coagulation

The most important single tool at the disposal of the chemist in charge of the operation of a coagulation plant is the jar test machine and there is no substitute for numerous and properly conducted jar tests for the control of such plants. Only by such test can the most economical dosage of coagulant be arrived at and the best settling flocs be obtained. There are many excellent papers in the literature describing the proper technique for such tests and they are also described in several of the contemporary text books and manuals. Every operator who does not have a jar test machine and is not using this test, should consult these references and institute such tests if he desires to obtain best results from his plant. Along with the jar test it is necessary to make regular and periodic determinations of color or turbidity, alkalinity, total hardness and pH value. The latter is especially important since it has to do with the stability of the treated water. In the case of most so-called "Filter" plants which employ coagulation, the treated effluent is apt to be quite soft and of relatively low pH value. There are a number of ways by which such waters may be stabilized and that subject will be discussed in one of the other papers which are to follow.

The ever-increasing popularity of the newer types of up-flow equipment emphasizes the need for a better understanding of coagulation since retention times are far less in these types of units than in the older and more conventional settling basins. For the same reason a great deal more vigilance and careful supervision is indicated in the operation of such plants. It is doubtful if anywhere in American chemical industry there is to be found a comparable example of the use of chemicals in the tonnages consumed by the water works industry and in the dilutions employed by it. The chemical reactions, not only of coagulation but of softening as well, are carried out in extremely low concentrations, and it is a tribute to the ingenuity, resourcefulness and scientific ability of the water works man that they are so successfully employed under these unusual conditions.

Continuous Activated Silica Preparation

by V. W. LANGWORTHY

Project Engineer, Omega Machine Co., Div. of B-I-F Industries, Inc., Providence, R. I.

NOW, ACTIVATED SILICA can be produced successfully on a continuous basis. Today, the time-and-space-consuming batch methods are outmoded although it must be acknowledged that continuous activation of silica by various reagents has evolved naturally from the old batch processes. Activated silica as a coagulant aid has been shown to be remarkable in its ability to assist in the clarification of warm or cold, turbid or colored surface waters. Properly prepared and applied it can reduce the load on sand filters by forming a floc which will ride out hydraulic surges in conventional or sludge blanket type clarifiers.

While the use of activated silica sol and the benefits to be derived from its use as a coagulant aid are fairly well appreciated, it is desirable to know more about additional factors involved. This paper discusses equipment requirements, operating techniques, characteristics of the common activating agents and elements entering into control of the activating process.

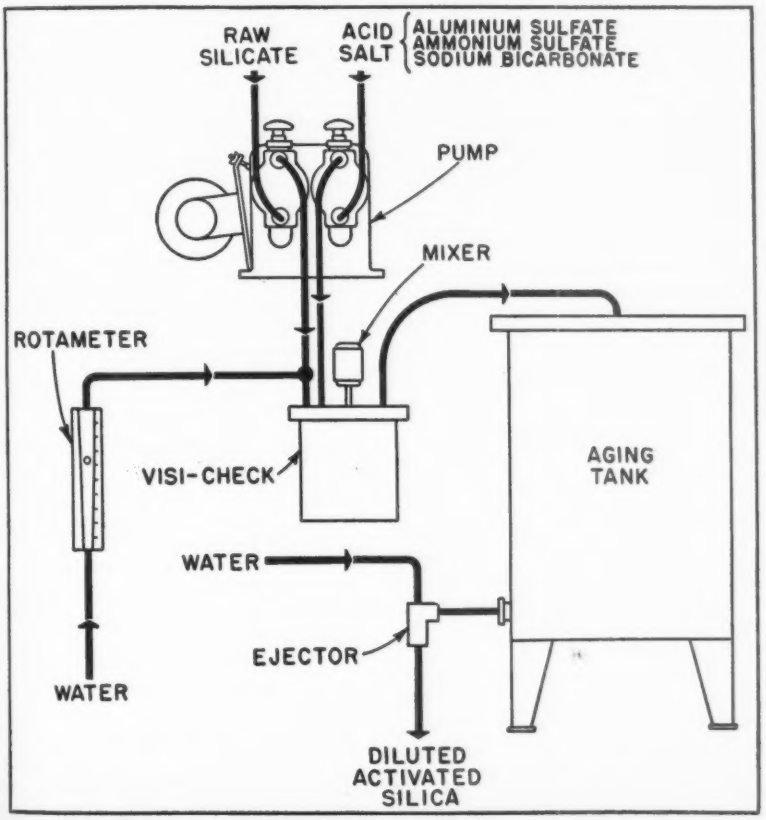


Fig. 1. FLOW diagram of continuous silica activation by acid salt.

Equipment Requirements

It is necessary that accurate control be maintained over the raw sodium silicate and activating agent to be used in the process. For this purpose equipment of choice is a positive displacement type pump, which must have reproducible accuracy and be capable of adjustment while in operation. Capacity and range of the pump must be compatable with other items of equipment employed.

At least one water meter should be provided to establish a known concentration of raw sodium silicate and activating agent. Variable orifice meters of the rotameter type have proved satisfactory for this purpose.

The importance of *intimate* and *complete* mixing between raw sodium silicate, activating agent and dilution water cannot be over-emphasized. The success or failure of the activated silica process largely depends on efficient mixing of controlled quantities of reagents at the proper concentrations. Hydraulic, mechanical or air mixing may be selected. Air mixing, however, may introduce troublesome reactions and likely will entail the expense of auxiliary air compressing and control equipment.

Aging

In order that a properly prepared activated silica sol may reach its maximum activity, a period of aging must be provided. Experience in the laboratory and on plant scale has indicated that aging requirements vary with the relative strengths of activating agent used in relation to a given volume of raw sodium silicate. In general, the higher ratios of activating agent per unit volume of raw sodium silicate require less aging. It has also been observed in rare instances, that formal aging of the silica sol may not be required to im-

prove coagulation in some raw waters. To produce a sufficiently active sol for most water treatment problems it is practicable to employ an aging period of approximately ten minutes by adjusting the strength of the activating agent to the point of greatest observed effect on flocculation.

Equipment for continuous silica activation should be supplied with aging capacity. This capacity should be sufficient to retain the sol at aging concentration for ten minutes when the rated *maximum* amount of activated silica is being produced. For example, if the total volume of raw silicate solution and solution of activating agent is 10 gallons per minute, at least a 100 gallon aging capacity vessel or chamber would be required to detain the sol for a ten-minute aging period.

Adjustable features should be provided in the aging unit so that ten-minute aging can be assured at all rates of activated silica production. Inasmuch as the process is continuous, aging equipment should be designed to minimize short circuiting and permit aging time adjustment without interruption to the process.

Transferral

The final item of equipment in continuous silica activation is that employed to conduct the active sol to the point of application. Gravity is the preferred means of delivery, but pumps of many types can and are being used for this purpose at numerous installations. The importance of *liberal* dilution of the activated silica sol for delivery to the point of application must be recognized. The tendency for objectional silica gel to form is virtually eliminated when the 10 minute aged sol is diluted. Therefore, the volume of sol being prepared should be diluted with an equal amount of water either for transfer or for holding purposes.

Avoiding Operating Errors

It is possible to provide certain features in continuous silica activating equipment which overcome some of the common operating errors. If water used by the equipment is required to pass through a flow switch, controlling all electrical circuitry, it becomes impossible to operate the equipment with insufficient water. This is an advantage in that it prevents starting the raw sodium silicate and activating agent flows without first turning on the diluting water supply to the unit.

Interference with the process can also be caused by failure of the raw sodium silicate pumps to deliver. Means should therefore be provided to detect this failure and to do something about it. If insufficient raw sodium silicate were delivered to the system, an excess of activating agent would result. This situation can lead to silica gel formation rapidly if allowed to continue. To avoid gelation, under this condition, it is therefore desirable either to shut off the supply of activating agent, or to provide copious amounts of rinse water automatically. An automatic rinse feature will permit resumption of normal operation merely by correcting the interference.

Automatic rinsing also eliminates the problem of human forgetfulness at shutdown time. In the event the operator shuts down the equipment, gelation is prevented by dilution effected through the automatic rinse system. This is greatly to be desired over cleaning out the system once gel has formed. Such an automatic rinse feature can be timed for a predetermined period, or the entire system can be turned off manually after rinsing. Under all circumstances, an automatic rinse arrangement should be incorporated in any continuous silica activating installation.

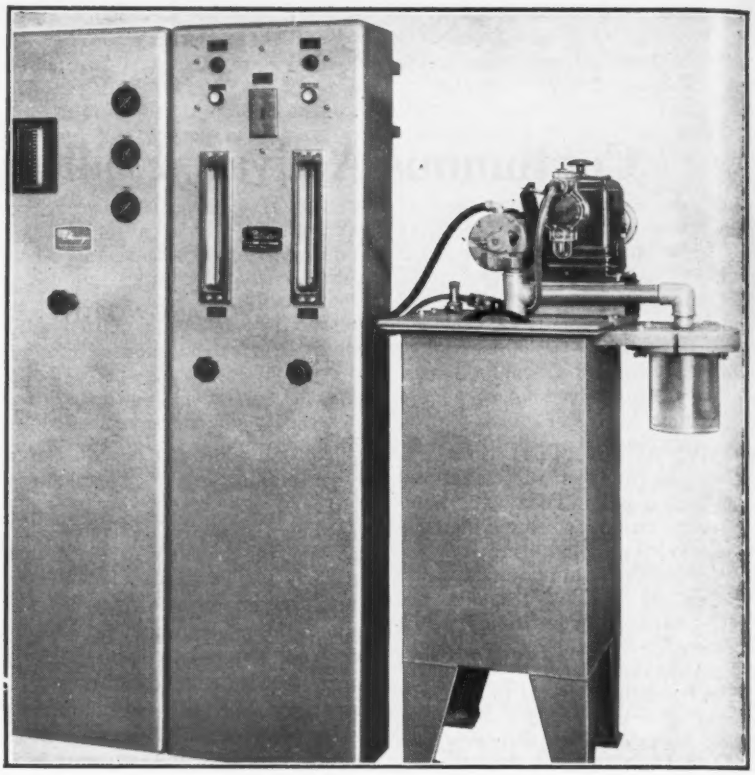


Fig. 2. CHLORINE type continuous silica activating equipment.

Constant strength chlorine device at left, control panel in center and mixing-aging system at right. Pump handles sodium silicate.

Selection of Activating Agent

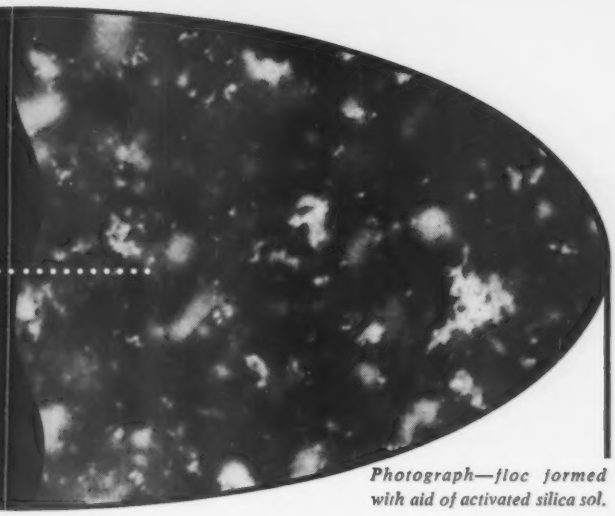
Several acidic reagents have been used successfully for continuously activating silica. Among these are chlorine, sulfuric acid, ammonium sulfate, aluminum sulfate, sodium bicarbonate and carbon dioxide. A typical composite flow diagram for acid salts is shown in Figure 1. Ferric sulfate also has been used as an activant in at least one West coast installation.

Selection of chlorine as the activating agent is popular, because chlorine used in the activation process is also available for disinfection or other purposes. Chlorine is simple to use and is readily available in most water treatment plants. Unfortunately, the ordinary chlorine gas feeding equipment does not lend itself readily for use with silica activating devices. The reason is that the regular chlorinator injector dilutes the chlorine solution too much.

Although chlorine is a desirable activating agent, it does have shortcomings. For example, where low rates of raw water having low chlorine demand require treatment with activated silica, too much chlorine often is added by the chlorine type equipment. This is an anomaly,

Activated Silica COAGULANT AIDS

PQ's N SODIUM SILICATE



Photograph—floc formed with aid of activated silica sol.

RAW AND WASTE WATER TREATMENT

Activated silica (made from N sodium silicate and a reactant chemical) used with a regular coagulant forms larger, denser, stronger floc and at a faster rate than when the coagulant is used alone. Floc enmeshes more impurities and suspended matter and settles out rapidly to produce clear, sparkling water. Treatment is effective with a wide variety of waters and in all popular flocculating and sedimentation equipment.

Activated silica sol is a dilute solution of sodium silicate, reacted with acids or acid salts such as sulfuric acid, carbon dioxide, ammonium sulphate, alum, chlorine, sodium silicofluoride or sodium bicarbonate. Four of these employed in the N-Sol Processes, outlined below, were developed by us and are licensed without royalty.

Preparation of the silica sol is done at the plant where it is used. Introduction into the water system can be made either by the "batch method" or by proportioning devices some of which continuously and automatically mix and feed the activated silica sol.

PQ ASSISTANCE

Samples of N sodium silicate (41° Baumé, 8.9% Na_2O, 28.7% SiO_2) and directions for making jar tests are available on request. PQ engineers are glad to share their knowledge in the use of activated silica sol to improve water quality. Ask for free literature, #52 series.

Sodium silicates are used also for controlling corrosion in water systems. *Further information on request.*

APPLICATION	PROCESS	REACTANTS	REMARKS
RAW WATER Improves quality Lengthens filter runs Removes high color Reduces turbidity Removes manganese Removes magnesium Removes calcium	N-SOL-A (U. S. Pat. 2,444,774)	ammonium sulphate	Easily prepared, either batch or continuous. Chloramines formed in waters previously treated with chlorine.
	N-SOL-B (U. S. Pat. 2,310,009)	alum	Reactant readily available, inexpensive.
WASTE WATER Recovers reusable solids Prevents stream pollution Clears effluent	N-SOL-C (U. S. Pat. 2,567,285)	chlorine	Reactant usually available where sterilization is normal practice.
IN SUCH INDUSTRIES AS: Paper Petroleum Metal Finishing Plating Food Textile	N-SOL-D	sodium bicarbonate	Used where an alkaline salt is desired. For boiler feed water where ammonia is not desired.
	SULFURIC	sulfuric acid	Used where sol of low alkalinity is desired.
ALSO Radio Active Waters	SILICOFLUORIDE*	sodium silicofluoride	Na_2SiF_6 available for fluoridation of water.

*Patent applied for

PHILADELPHIA QUARTZ COMPANY
1137 Public Ledger Building • Philadelphia 6, Pennsylvania

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PQ SOLUBLE SILICATES
N-SOL PROCESSES

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wherein any reduction in chlorine used produces an inferior activated silica. Therefore, while chlorine is readily available, it will not in every case be the best reagent to use in the silica activating process. A typical chlorine activated silica unit is shown in Fig. 2.

Sulfuric acid is considered the least expensive activating reagent. Many operators, however, prefer not to handle the acid unless absolutely necessary. With adequate precautions, sulfuric acid may be used successfully at both large and small plants as a silica activant. Figure 3 illustrates a sulfuric acid type silica activator.

Ammonium sulfate is often used in connection with the chlorine-ammonia process at water treatment plants. It is also readily available in tonnage lots at reasonable prices. The technical grade product is crystalline, free flowing and possesses a high solubility in water. It is a good activating agent where small amounts of ammonia will not interfere in the treatment process, or with subsequent water uses.

Aluminum sulfate has enjoyed widespread use as a coagulant in water treatment plants in this country. It is readily available and easy to handle, These characteristics plus its good solubility render it highly desirable as an activating agent. It should be noted, too, that a portion of the alum used in the activation process remains available as aluminum hydroxide for use as a coagulant.

Sodium bicarbonate is an inexpensive reagent highly satisfactory for use as an activant. It has a comparatively low solubility in water which makes it less suitable than the acid salts already mentioned. The weak acid tendency, however, provides a process which is easy to control because of the high buffering action of the bicarbonate. Also, the tendency to gel is less dominant in the bicarbonate process than in the alum or ammonium sulfate methods.

Carbon dioxide has been used successfully in batch-wise preparation of activated silica. Its adaptation to continuous processes has been limited primarily due to its low solubility in water. The gas is not readily available at economical prices in tonnage lots, nor is the solid product (dry ice) easily adaptable for use. At least one Florida installation uses flue gas as a source of carbon dioxide, but this practice has not become widespread.

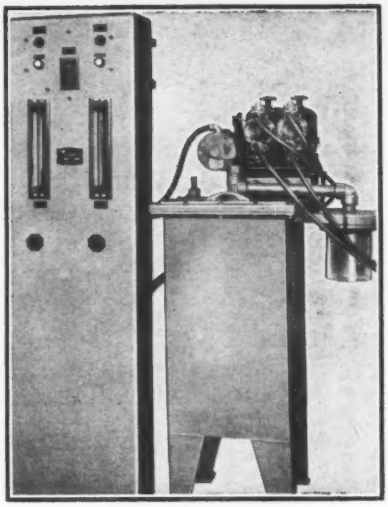

Fig. 3. SULPHURIC acid type continuous silica activating equipment.

Activating agent selection should be made, in part, on the basis of the reagent which produces the best coagulant aid, helpful in solving the local coagulation problem. Many plant operators use jar tests as a means of selecting appropriate coagulant dosage. The same test will indicate the silica activating agent best suited to local raw water conditions.

Interchangeability of activating agents is simplified when dry reagents are used. The problem is simply one of selecting the chemical, dissolving it and delivering the proper volume of constant strength solution to the mixing and aging equipment. Equipment used in feeding gaseous reagents does not possess this flexibility.

Process Control

Silica activation may be considered a neutralization reaction. The end product sought is a controlled suspension of colloidal silica. It should be possible to control the activation process by titration, gel time, pH, conductivity, viscosity, or light transmittancy. It has been found that titration is a reliable means of control. Total alkalinity of the aged sol will depend on the activating agent used.

Where chlorine is the activating agent, the titration for available chlorine may be used as a guide. In the acid salt reactions straight titrations for total alkalinity may be used. The objective is to obtain the best sol short of gel formation. This means that the titration end point selected should give a gel time longer than the aging period required by the activating equipment.

Gel time can be used as a means of determining the aging period, no other tests being required. The gel time for certain type sols may be extremely long, rendering the results obsolete by the time they are obtained. Short gel time, such as that obtained where chlorine or sulfuric acid is used, is more appropriate for use as a guide. Gel time remains valuable usually as a check against the easily performed and reliable titration.

The remaining control procedures, pH, conductivity, viscosity, and transmittancy all have application where precise study and exhaustive data are desired. However, the normal operation of activated silica equipment does not require or justify expenditure for the necessary instruments required for these tests.

In Summary

Continuous silica activation requires dependable equipment accurately calibrated if satisfactory results are to be obtained. The process should include efficient mixing and provision for control over the aging period. It is desirable to include automatic interlocks to guard against improper start-up and to provide rinsing at shutdown. While these features are not mandatory, they contribute an intangible peace of mind to the operator and are insurance against non-performance.

Ideally, the silica activating equipment should provide for interchangeability of activating agents. This feature allows the operator freedom of choice of activant both before and after equipment purchase. Activant selection should be based primarily on the results produced; secondary considerations, however, are availability, safety, economy and chemical characteristics.

The activation process may be controlled in several ways. Titration and gel time have proved to be the most practical means available.

Taste and Odor Problems

at Valparaiso, Ind.

by RICHARD COOTE

Superintendent of Water Filtration, Valparaiso, Ind.

Tastes and odors have constituted a major problem at the Valparaiso, Indiana, water treatment plant for several years. Chief among the causes of the trouble have been the turnover periods of the supply lake and the algae growths in this same reservoir.

Source of Supply

The main supply is taken from a small lake of 80-acre area and a drainage area of about 2.8 square miles. Rainfall is the only source of replenishment, as there are no springs in the lake. During periods of heavy rainfall the water is very turbid and contains high concentrations of organic matter, algae, and all types of foreign matter from the runoff.

Increasing demand on this small lake, combined with evaporation, has required that during very dry periods well water be pumped into the lake from deep wells, the amount increasing yearly with the increased demand. For example, in 1956 raw water pumpage was 658.5 million gallons, but 367.9 million gallons of well water were pumped into the lake during the year. The wells were run about 4½ months during the year to help hold the lake level during the dry period.

There are two reasons for not pumping the well water directly into the system. The first is that the well water is hard (26 grains per gallon) and high in iron content (2.0 to 5.0 ppm). By pumping water of this quality into the lake first, only 0 to 0.3 ppm iron is contained in the plant's raw water and the hardness remains under 15 grains per gallon.

The second reason for pumping to the lake is that the water level would drop badly from evaporation alone. It is obvious that the greater demands have made this system of supply limited for future usefulness. Eventually a supplemental supply must be developed to help the present supply: a survey is now under way for an addition to the supply for the near future.

Turnover Periods

In the late fall, and again in February, the lake "turns over" due to temperature changes. During these periods a very objectionable taste is experienced, as the lake has a muck bottom.

Prior to 1949 this effect was even more pronounced. This came about because the intake was very close to the bottom (2-ft riser) and was in about a foot of muck. During the turnover a brown musty-smelling water was pumped into the plant. At times this water had a threshold odor of 40 or better and had a very bitter taste. Small doses of activated carbon would bring the threshold odor down to an acceptable point, but the taste was marked and doses as high as 125 pounds per million gallons were necessary to give a palatable water.

When the new intake was planned in 1948 a raft was anchored near the site and water samples were taken from different depths for a period of two months. Complete analyses were run so as to establish the level at which the best water of uniform quality could be obtained. After completion of the test run the new intake was set with a 12-ft riser. This brought

the port to the depth at which the most uniform water was obtained, most of the time giving a much better quality of raw water easier to treat during the turnover periods, which are now shorter and are more easily handled with smaller carbon doses.

The previously mentioned pumpage from the wells to the reservoir lake has brought about one noticeable result in the last few years of greater demand—the turnover periods are either very mild or are nonexistant.

Algae Problems

The algae problem still is a major one, but it has been made easier to control through improved laboratory testing.

In May 1955 there was a spell of bad taste and odor; the water leaving the plant was not good. However, from this necessity, new feed methods and better laboratory control were worked out. During 1956 and 1957 these conditions have been much improved.

First, laboratory control is more complete. Every month algae counts are made on the raw water during at least one week. These counts are on the number per milliliter and the types of algae. This counting program has been in effect long enough that it now is possible to tell which algae produce the bad odors, and the count at which treatment must begin in order to keep the threshold odor from getting too high. At times the counts change rapidly as to number and types. Therefore, year-round checks provide considerable information for use in taste and odor control.

As an example, during a recent period of poor tastes (November 8-25, 1956) the following results were obtained:

Raw water:

Threshold odor number	10
Taste threshold number	7
Algae count, no./ml	530
Algae types	*Aphanizomenon, Synura, Uroglena*
Temperature, °F	38

Tap water:

Threshold odor number	2
Taste threshold number	2
Carbon dose, lb/mg	65
Taste	None
Odor	Slightly earthy when hot

The October algae counts had been low but by early November the *Aphanizomenon* and *Synura* were increasing. After November 25 the counts again dropped and the raw water threshold odor decreased to 5, which needs no treatment.

Again in April 1957 there were were heavy rains. The turbidity of the raw water was high; color and organic matter increased as runoff from the heavy rains entered the lake, and temperature and chlorine demand increased.

Water Temperature Important

Two streams enter the reservoir (Flint Lake). The overflow is located just behind the filter plant, creating a small body of water there during periods of high lake level. By fall this area is emptied, but in spring this shallow body of water is a good breeding spot for algae when there is no overflow. This is the area where the well pumpage is discharged into the lake, thereby helping to keep the shallow part fresh and cutting the algae mat. Temperatures in this water reach the 90's during the daylight hours.

Temperature of the raw water entering the plant is of great importance in controlling the tastes and odors of the finished water. Because the reservoir is small and shallow, the temperature rises raidly in the spring and does not change until late in the fall.

For example, raw water temperatures are in the high 50's by mid-April, reach the 70's by early June, the high 70's by mid-June, and remain at that level until early October, not dropping below the high 50's until very cold weather in November. At that time the sudden temperature drop causes algae count variations that may cause short periods of taste problems.

Temperature of the water going to the distribution system also presents a problem, because the higher the temperature the more noticeable are the tastes and odors. For example, odors that would not be noticed in a water at 55°F or 60°F are very noticeable in the same water at 70°F, and more so at 75°F.

Several years ago a series of threshold odor and taste tests was run to establish palatable threshold numbers for both characteristics. These tests established that a hot threshold odor

TABLE 1

Summary of Laboratory and Treatment Data During Taste and Odor Periods, 1957

Date	Threshold				Water Temp., °F	lb/mil gal Dosage,		Algae	
	Raw		Tap						
	Hot	Cold	Hot	Cold		Cl[2]	C	Count, no./ml	Types
May 5	7[1]	T	4[3]	T	60	40	0	120	Synedra, Asterionella, Anurea
May 16	10[3]	3[3]	7[2]	3	63	45	0	173	Ceratium, Asterionella, Synedra
May 20	15[3]	2[4]	2[4]	1	60	38	56	1,370	Vorticella, Cyclops, Asterionella, Notholca, Microcystis
May 29	9[3]	1	1	0	63	48	42	595	Cyclotella, Cyclops, Synedra, Asterionella
June 8	14[5]	3[1]	7[1]	1	67	45	0	1,400	Cyclops, Peridinium, Vorticella, Synedra, Stephenodiscus
June 9	16[5]	3[6]	3[6]	T	72	35	45	1,450	Cyclops, Peridinium, Vorticella, Synedra, Stephenodiscus
June 17	18[5]	2	4[3]	1	76	35	45	1,800	Dinobryon, Synedra, Anurea, Asterionella, Melosira
June 24	15[5]	2	3[1]	0	76	42	67	1,820	Dinobryon, Synedra, Anurea, Asterionella, Melosira
July 3	14[7]	1	2[1]	0	74	46	71	1,044	Anabaena, Microcystic, Anurea, Pediastrum, Ceratium, Synedra
July 8	8	0	2	0	75	42	62	435	Melosira, Ceratium, Asterionella, Anurea
July 13	3	0	2	0	74	58	0	250	Melosira, Ceratium, Asterionella, Anurea

[1]Musty. [2]Weedy. [3]Sour musty. [4]Faint musty. [5]Fishy. [6]Aromatic. [7]Moldy.

of 5 on the plant tap water was the maximum that could be passed without consumer complaints. Tastewise, the maximum allowable is a threshold of 4. By holding to these values taste and odor conditions are under control, but at high temperatures even lower thresholds are sought to be sure of satisfactory results. Table 1 summarizes the laboratory results and the treatment during taste and odor periods in the spring of 1957.

Continuing Trends

Improved laboratory control has resulted in better taste and odor control. Use of the threshold odor and taste tests permits correlation of these with algae counts as periods of taste and odor develop each year. The longer the records are maintained the easier should control become, as there is always a similar trend; that is, algae increases of certain types occur at about the same time resulting in similar odor periods. With this forewarning, corrective treatment can be initiated before odors can cause consumer complaints.

Application Point Important

Another important factor in taste and odor control is the application point of the chemicals to provide sufficient contact time.

In the Valparaiso plant short settling time was already a factor. With the increasing demand for water the condition became acute. However, carbon could not be used because the short detention time resulted in so much carryover of carbon to the filters that it passed through them whenever the dose was over 15 pounds per million gallons. This caused "black" water in the distribution system—and consumer complaints. When combined with bad taste or odor the situation was serious, as there was no way of producing a palatable water.

Use of chlorine dioxide proved helpful in that it either removed or reduced the odor and taste period to the point that consumer complaints were markedly reduced or entirely eliminated. Although this method of control was expensive at times and did not always give the best results, it was greatly beneficial until plant expansion could be arranged.

Plant Improvements

The plant expansion was completed in 1950. Addition of a 485,000-gallon clarifier in series with the old settling basin provided sufficient settling time to allow use of carbon. Increased mixing time insures better flocculation, with a water of better settling quality entering the clarifier, and a clearer water entering the filters. Better settling has removed much of the foreign matter, thus helping with control of the algae conditions.

Installation of additional filters also helped considerably, as the filtering rate was considerably reduced, thus eliminating carbon passage from the picture.

With these improvements completed, carbon could be used for odor control. It has been found that much better results are obtained with less carbon if the carbon can be applied first and sufficient time allowed for adsorption before breakpoint chlorination is applied.

For the first few years after the plant expansion carbon was added to the raw water basin and chlorine was not added until the middle of the mixing basin (about 15 minutes later in the flow pattern). This proved satisfactory, giving good odor removal with nominal carbon feeds. When no carbon was used the chlorine was added in the raw water basin.

In 1954 no carbon was used, as the raw water was of very good quality. Good settling and breakpoint chlorination sufficed.

In 1955, however, raw water of very bad quality required a return to carbon dosing to insure a palatable final water. The carbon was fed as previously described. However, during the intervening two years consumption had increased greatly and although more carbon was used (14 ppm compared with a previous high of 9 ppm), threshold values were very high.

With the poor results from the carbon, it was decided that the carbon contact time prior to the chlorine feed had been reduced because of the increased flow rate. To increase the flow time between the two application points, the chlorine feed point was moved to the outlet of the new clarifier (actually the inlet of the old settling basin). At peak flow of 3 mgd this gave the carbon a contact period of about 4 hours before the chlorine addition. Carbon dosage was immediately reduced and a palatable water was obtained. Chlorine also could be reduced, thus reducing costs still further.

Since this time, whenever taste and odor conditions arise these changes in chemical application are made, giving maximum advantage of the carbon and chlorine in turning out a good finished product.

One disadvantage encountered in this method of chemical feeding was that algae growths in the clarifier became very heavy. This condition was kept under control, however, by additional chlorine dosing ahead of the clarifier during short periods at night. This did not seem to affect the good quality of the plant effluent, yet it held the algae under control.

Summary

By operating the plant in the manner described, with close plant and laboratory control, it is felt that even under severely adverse raw water conditions a palatable water that will meet with customer approval can be produced. This is a factor that over the years has become a "must."

Since it has become possible to use carbon at all, low dosages remove the bitter or musty tastes and the fairly low (T.O. 6) odors usually encountered in the cold raw water. Thus, these conditions do not create the problem generated by the spring and early summer algae. However, increasing the carbon contact time by moving the point of chlorine application has eliminated this problem as well.

With the overloading of filtration plants due to increased demands, the quality of the finished water is bound to be affected. To meet the requirements of a good finished product all means of obtaining it must be explored. It must be remembered that contact time is very important in water treatment and that overload plants lack this essential element.

To preclude any repetition of the past problem, Valparaiso is currently considering new supply possibilities and planning for future plant expansion while still producing the best product possible.

Tastes and Odors in Water

by M. B. ETTINGER and A. A. ROSEN

respectively, Chief, Chemistry and Physics, Water Supply and Water Pollution Program, and Research Chemist; U. S. PHS Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

Estimates based on "population equivalents"[1] rate industrial wastes as responsible for more than twice as much stream pollution in the U. S. as municipal sewage discharges. It has been further estimated that between 1950 and 1975 population will increase by about one-third and industrial production will double. Estimates by chemical industry[2] of future expansion make these statements on industrial growth seem highly conservative. Production increase will obviously be accompanied by increasing use of water.

The future growth of water use is likely to occur in a framework of shrinking availability of surface water. Supplementary irrigation in areas which formerly depended solely on rainfall is increasing rapidly. This consumption of water occurs during dry summer periods, when most streams have their lowest flow of the year, and it has been estimated[3] that it can use the entire flow of many streams, even if only a small fraction of 1 per cent of the land in a watershed is irrigated.

Municipal use of water is increasing faster than population. Thus, the average urban dweller now uses 150 gpd, whereas 30 years ago he used only 20 gpd.[4] Recreational use of water is harder to assess, but both increased leisure time and increased income are causing the public to demand more water resources for recreation.

Requirements for discharge of wastes to surface waters will, of necessity, become increasingly critical, and one of the most critical items is likely to be the taste and odor imparted to water by organic materials in wastes. In 1948 there were 422 water plants in the U. S. serving communities having populations in excess of 25,000; 133 of these communities, with a population of about 14,000,000, included some provision for taste and odor control in their water plants.[5] In 1954, there were 570 water plants serving communities having populations in excess of 25,000; 201 of these plants, serving about 34,000,000 people, included facilities for taste and odor control.[6] This well-defined trend in water plant facilities and practice clearly indicated the rapidly increasing pressures and costs borne by water plants because of impairment of raw water quality by odorous material.

The total taste and odor problem has many facets. A severe and sustained drought forced Dallas, Tex., to supplement a normally adequate municipal water source with unsuitably salty water. The same drought caused Chanute, Kan., to fall back on treated sewage effluents as a raw water supply in order to keep water in its faucets. The tainting of fish flesh by chemicals in surface waters is another type of taste and odor problem. In streams and lakes the biological synthesis of chemicals causing taste and odor is becoming more important because of man-caused increases in stream fertility. These are all matters for serious concern. This discussion is limited, however, largely to consideration of chemical impairment of water quality for municipal or industrial use.

Sources of Tastes and Odors

Odors may be attributed to chemical materials produced by biological growths and to the presence of organic pollutants or other objectionable matter naturally present in the water. The distinction is not clear-cut, as the introduction of a pollutant may greatly stimulate the growth of objectionable organisms. Chemical oxidation of carbonaceous material increases the supply of carbon dioxide, which stimulates organic growth. Nitrogen and phosphorus from sewage also stimulate the growth of photosynthetic organisms.

Incredibly small amounts of many odorous materials can cause sensory stimulation. Experiments in the Sanitary Engineering Center laboratories have frequently yielded a detectable odor from recovered materials in concentrations of 2 ppb and less. Sometimes materials have been isolated (but unfortunately not identified) which could be detected by odor in concentrations as low as 0.01 ppb. Very substantial odors, therefore, can be caused by extremely minute amounts of such material. In terms of quantities that are easier to visualize, a single teaspoonful of pollutant can impart odor to a million gallons of water.

Utilizing adsorption and extraction techniques for concentrating the odor-

ous organic pollutants of drinking water supplies, it has been found that neutral compounds are usually the most abundant odorous organic pollutants. These neutral organic materials usually have intense tastes and odors. The second most abundant group of odorous materials is usually the organic acids, which also have intense odors and tastes. Small quantities of other materials have been recovered, including organic bases (which may have a tobacco-like odor), water-soluble compounds (which frequently have caramel-like odors), and a group usually referred to as the "weak acids," which include phenolic compounds, if they are present in the water.

Phenolic compounds are present infrequently and have probably been over-emphasized because they are one of the few materials detectable by analytical techniques generally available in water plant laboratories. Before chlorination, commonly occurring phenolic materials have but little taste or odor. Ordinary chlorination of these materials greatly increases the taste and odor; free residual chlorination destroys the odor.

Characteristics of Tastes and Odors

Odors are subject to seasonal cycles. Industrial pollutants show reasonably well-defined patterns of behavior and may be divided into two general categories, depending upon whether they are susceptible or resistant to biological destruction during transportation in surface waters.

In the first class, with pollutants subject to biological destruction, odor intensity is likely to reach a peak during the winter months. Unless the water plant is immediately adjacent to the source of pollution, the peak winter odor intensity is likely to occur when the river undergoes a moderate rise, especially after a period of low water. This is caused by a combination of scouring of bottom deposits and more efficient transportation of dissolved materials. Although the rise in the river increases the amount of dilution water, the reduction in the time of travel between the source of pollution and the point of water consumption is likely to result in an overall increase in the amount of odor-producing material reaching the water plant inlet. Where a river freezes over solidly and perhaps becomes anaerobic in certain areas, maximum odor loads may occur during low-flow periods in the winter.

The second class includes those pollutants resistant to destruction during transportation in surface waters. Fortunately, few odorous materials of industrial origin are in this group. When a water source is polluted by such materials, maximum odor difficulty or other disturbance may accompany any low-flow period.

Algal blooms or spurts of microbiological growth frequently have a definite seasonal incidence and can be expected at reasonably well-defined periods at each locality. Local and regional experience is the best guide available and should be fully explored.

Sometimes algal growth and industrial pollution may take turns as the dominant nuisance in a particular situation. In one water plant studied, phenol from a nearby refinery is present thoughout the year, and there is usually a very definite chlorophenolic taste in the water. At certain times of the year, however, algal blooms cause tastes and odors of such intensity that the phenol odors are not noticed.

The river flush-out is sometimes the cause of acute taste and odor problems as well as other stream disorders. For example, it was recently observed[7] that organic wastes from a refinery were not transported by the receiving stream and apparently were subject to bottom storage with very incomplete self-purification. Periodic river rises flushed out the bottom deposits. In the authors' experience some of the most severe water quality problems have been frequently associated with the first river rise after a long dry spell, with the accompanying flush-out of pollutional material retained in bottom deposits. It is believed that such incidents are sometimes wrongly attributed to industrial spillage or dumping.

The taste and odor of a raw water present problems at the water plant which must be faced on several fronts. These include the following considerations:

1. The water must be made palatable and acceptable to almost the entire using population.

2. Surface supplies must be disinfected to give water of satisfactory bacteriological quality.

3. The cost of high-quality water must be compatible with the ability of the community and its industrial consumers of "city" water to pay for for the water.

The control of water quality by water treatment has been discussed recently by Ettinger and Middleton[8] and presentation of this material is beyond the scope of the present discussion. It is appropriate, however, to discuss simple approaches to the evaluation of the odor-producing potential of organic wastes. To do this intelligently it is necessary to take at least nominal cognizance of the nature of water treatment procedures currently in use.

Water supplies taken from surface sources subject to pollution almost invariably are chlorinated and the taste and odor of the water after chlorination become important factors. Chlorine frequently reacts with organic

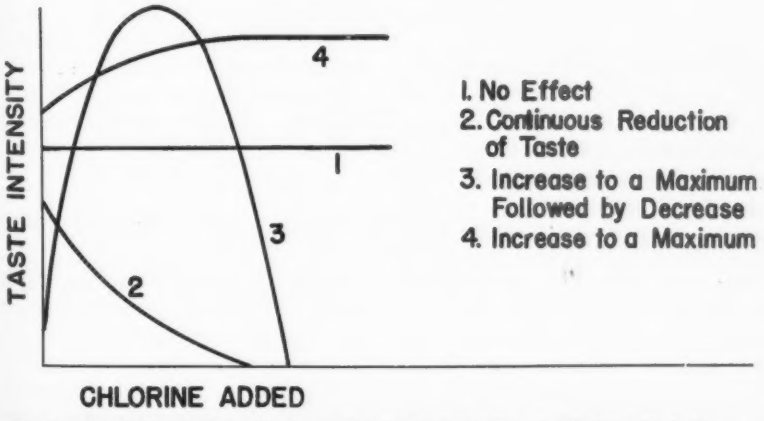

Fig. 1—CHLORINATION effects on the taste intensity of dilutions in industrial wastes.

material to develop or decrease odor. When this occurs the odor intensity will vary with the amount of chlorine added. Figure 1 is a schematic presentation of this pattern of behavior.

The reactions occurring between chlorine and waste components are sometimes influenced by dilution. Because water treatment plants cannot handle extremely polluted water, such as an industrial waste stream, the organic waste under consideration should be suitably diluted to concentration levels approximating those handled by a severely loaded water plant. Chlorine reactions produce acid, making it desirable to buffer the solution being chlorinated with sodium bicarbonate, thus simulating the bicarbonates which buffer natural waters. In large water distribution systems, a long period elapses between the time water leaves the treatment plant and the time it reaches the most distant consumer. Odors which develop in a water distribution system as the result of slow reactions between residual chlorine and organic contaminants must be given due consideration.

Odor is necessarily a subjective quantity, amenable to measurement and interpretation only in terms of people. This requires that odor test procedures and their interpretation be based on the characteristics of the reactions of people to odors.

Figure 2 shows a log-probability chart of the variation in the amount of a specific chemical, n-butyl alcohol, required to give a detectable odor in a series of 785 tests made by 33 water plant operators over a five-month period. This chart leads rather simply to certain interpretations. In reaction to the n-butyl alcohol, the most sensitive 5 per cent of the population is at least 17 times as sensitive as the least sensitive 5 per cent. The "50 per cent" man, or median observer, has less than one-quarter the sensitivity of the most sensitive 5 per cent, and is more than four times as sensitive as the least sensitive 5 per cent of the population.

Obviously, any attempt at quantitative appraisal of odor requires a large random group of observers, or a panel of several people selected because they show at least reasonably good capacity for odor detection in general. The most meaningful value with a small panel is the panel median T.O. Use of the "median" prevents one unusually dull or unusually sensitive observer from throwing the panel results too far one way or another. If a mean is used it should be the geometric mean.

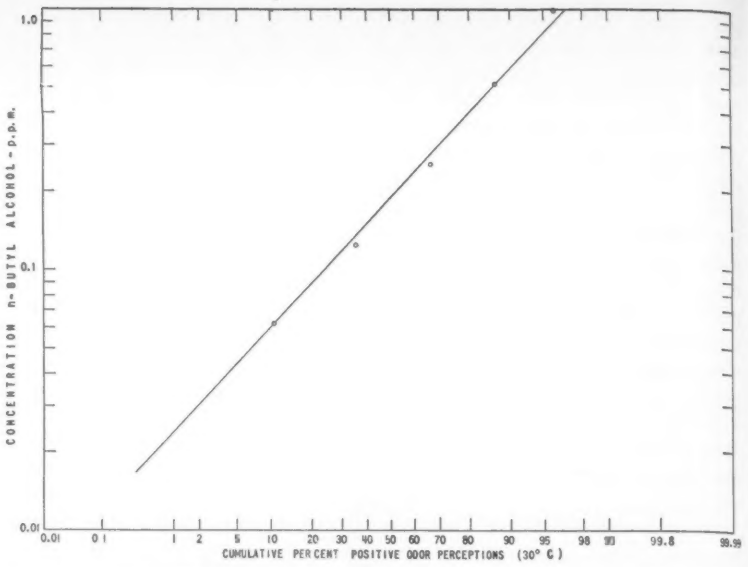

Fig. 2—CHARACTERISTICS of operator response to n-butyl alcohol (785 observations, 33 operators).

There is no real advantage in attempts to characterize odor strength too precisely. In the laboratories of the Sanitary Engineering Center no attempt is made to differentiate between odor intensities of solutions that differ by a concentration factor of less than two.

Observers have further characteristics which require consideration in a prescribed test procedure. They tend to lose sensitivity when asked to detect a trace of a material after exposure to a gross quantity of the same material. Because observers are suggestible, it is difficult to secure an impartial judgment without asking the observer to discriminate between unknowns and a blank. Fatigue and boredom combine to make observers less sensitive and more erratic during prolonged odor observations. Further details of ideas on odor and taste-testing protocol have been described elsewhere[9] and need not be repeated here.

Another facet of the problem of assaying the odor-producing potential of wastes lies in the question of whether or not odors are additive. To oversimplify, assume (a) a chemical plant has only two odorous plant waste streams, one of which contains only an organic alcohol, and a second which contains only a pyridine base; and (b) that the total plant stream enters a body of water in which neither compound will be sufficiently concentrated to give a detectable concentration on the basis of concentration in the waste stream.

Questions to be answered are:

1. Are the waste streams unimportant in terms of stream odors, since they will be present below threshold concentration?

2. Can both waste streams together give the stream an odor increase if neither one can do it alone?

Assuming that chemical reactions are not invloved, the answers to these questions lie in the determination of whether odor stimuli by unrelated individual materials are additive and/or synergistic or whether they are nonadditive and/or antagonistic. If it be assumed that the threshold concentration of material A is a and the threshold concentration of material B is b, the question is posed by the statement:

$$\frac{a}{2} + \frac{b}{2} \begin{matrix} > \\ = \\ < \end{matrix} \text{TOC}$$

where TOC is the threshold odor concentration.

Investigation of this question is just getting well underway in the Sanitary Engineering Center laboratories. So far human response to odor stimuli by combinations of two and three specific chemicals at a time have been measured, but only a limited number of

chemicals have been investigated. To date the findings give the answer:

$$\frac{a}{2} + \frac{b}{2} > \text{TOC}$$

There is little reason to believe that this finding will not hold up in most circumstances and it represents the best basis presently available for considering the questions involved. In words, the mathematical notations say that human sensory response to individual odorous chemicals in a mixture is at least additive and that it may be greater than an additive response.

Accepting this premise, the questions listed previously can now be answered, as follows:

1. The hypothetical waste streams suggested previously are important to stream odor quality because they join with other materials to increase the total odor load, even though the waste streams individually will not add a threshold concentration of the chemicals they contain.

2. Even though waste streams are unlike in odor or chemical structure and do not react, the two streams can jointly impart detectable odor to the receiving stream even though neither one can do it alone.

The additive, or even synergistic, character of odor stimuli is important in approaching such complicated situations as those presented by the boundary waters. Few plants can be charged with contributing enough organic material to give detectable taste and odor to 175,000 cfs of water. Each waste source must, however, be regarded as a definite contributor to total impairment of odor quality.

Conclusions

The evident trend in the taste and odor quality of raw water is downward, but estimates of stream pollution in terms of population equivalents show an ever-upward trend. Tests and odor loads may be expected to increase more rapidly than loads in terms of "population equivalents" because of many factors, some of which have already been discussed.

Subject to relief by self-purification in streams, organic pollutants of surface waters present an additive assault on water quality, and each tangible organic source is a factor in determining the odor of the resulting water.

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Chlorination of Water

by EDMUND J. LAUBUSCH

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Considerable progress has been made in the use and development of chlorination practices at sanitary installations during the past half century (see Fig. I-1). Out of these years of experiment, experience and intelligent operation have crystallized certain practices and policies well worth the consideration of persons in any way associated with the handling or use of chlorine.

Development

Fifty years have passed since chlorine was first introduced on a plant scale to the Boonton reservoir supply of the Jersey City, N. J. water works system. Clearly, the effectiveness of continuous chlorine disinfection in practically eliminating such waterborne diseases as typhoid and cholera is responsible for its wide spread adoption and continuous development in the United States (see Fig. I-2).

Not all of the public health protection afforded by modern water treatment technology can be attributed to chlorination practices. That the value of chlorine disinfection is recognized is evidenced by the fact that almost 50 per cent of all existing water treatment plants in this country in 1948 employed it as the only form of treatment. Moreover, in that same year (see Fig. I-3) a total of 6135 plants, serving more than 80 million people, employed chlorine disinfection alone or in conjunction with other water treatment processes. This represented some 87.8 per cent of the population served by *all* community water works systems, both with and without treatment.

In water chlorination, as in the somewhat allied field of sewage chlorination, there often is an unfortunate tendency to follow blindly in the wake of authority or novelty, forgetful that no two problems are identical and that a treatment regimen, excellently suitable in one case, may be totally inapplicable in another. The following discussion relates patricularly to fundamental principles of water chlorination although much of it applies equally to the chlorination of sewage and other wastes.

Chlorination Theory—Chemical & Biological Effects

The reaction mechanisms involved in the addition of chlorine to water superficially appear to be very simple. In reality, however, this is not at all the case: First, waters to which chlorine is added are not simply H_2O but are, in fact, extremely complex solutions of many elements and their compounds, including varying amounts of numerous organic substances of animal, vegetable, and synthetic origin; and, secondly, the reaction does not yield a simple addition compound, xCl_2yH_2O. When chlorine is added to waste-bearing waters, the situation is even more complex.

When chlorine (a solution of chlorine gas or hypochlorite) is added to water—reducing the reaction to its most elementary form—a mixture of hypochlorous acid (HOCl) and hydrochloric acid (HCl) is formed:

$$Cl_2 + H_2O \rightleftarrows HOCl + HCl$$

The hypochlorous acid ionizes or dissociates into hydrogen and hypochlorite ions:

$$HOCl \rightarrow H^+ + OCl^-$$

Both reactions are dependent upon the pH value of the water. From its mass action equation it can be readily demonstrated that molecular chlorine can not exist in waters above pH 3.0. Between pH 6.0 and 8.5 there occurs a very sharp change from undissociated to completely dissociated hypochlorous acid. Chlorine exists predominately as HOCl at low pH levels; above pH 7.5 hypochlorite ions (OCl^-) predominate, while above pH 9.5 chlorine exists almost entirely as OCl^- (see Fig. I-4).

The utility of chlorine in water treatment is attributable to its toxicological characteristics and its high oxidative capacity (see Figs. 1-5, 6). Chlorine is employed either to destroy or control bacteria, (or both) or to modify the chemical characteristics of the water being treated. Among those variable components of natural water supplies that often affect water chlorination are:

- Alkalinity
- Oxidizable metals
- Other oxidizable inorganic substances
- Ammonia and amines
- Oxidizable organic substances
- Bacteria and other organisms

Alkalinity. Hardness-producing materials, principally the carbonates and bicarbonates of calcium and magnesium, tend to buffer water against significant changes in pH that otherwise would accompany the addition of small amounts of acids and alkalies.

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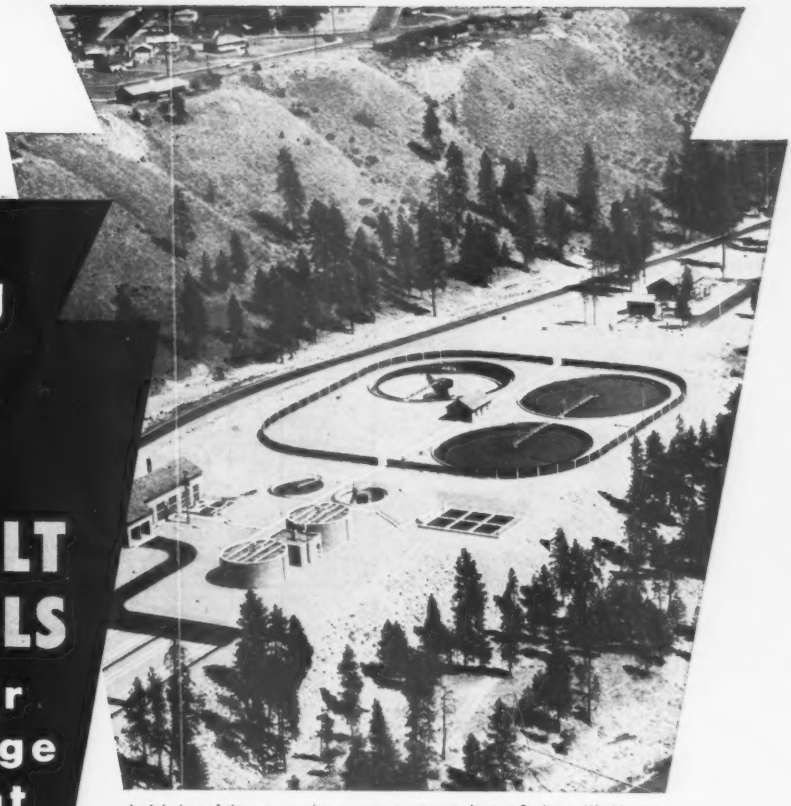

Aerial view of the new, modern sewage treatment plant at Spokane, Washington

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As noted later, if chlorination is to be efficacious, either as a chemical oxidant or for disinfection, an optimum pH range must be maintained.

From the equation of the hydrolysis of chlorine it is evident that the hypochlorous and hydrochloric acids produced will tend to lower the pH; each part of chlorine added reduces the alkalinity by about 1.22 parts (as $CaCO_3$).* When sufficient chlorine is applied to deplete the natural alkalinity to such an extent that the pH is substantially decreased, then pH correction may be indicated as an auxiliary treatment. (Solutions of hypochlorite always contain an excess of alkali which, if anything, will tend to raise the pH value, usually by insignificant amounts.)

Oxidizable Metals. In water treatment, the primary method of iron and manganese reduction is by oxidation of soluble ferrous and manganous forms to the insoluble hydroxides, followed by precipitation. Where chlorination is employed for disinfection, and in the presence of these metals, sufficient chlorine must be added to satisfy the bacteriological demand as well as that from these sources.

If chlorine is used as the oxidizing agent, iron or manganese will not be removed unless the pH is high enough for hydroxide formation. For iron removal the optimum pH is 7.0 or above, and for manganese removal the optimum pH is 10. About 0.6 and 1.3 parts* of chlorine are required, respectively, for each part of Fe and Mn removed, and about 0.9 and 3.4 parts of alkalinity (as $CaCO_3$) are consumed.

Chloramines do not enter vigorously in these oxidation reactions. For satisfactory manganese removal, free available chlorine (as distinct from combined available chlorine) should exist.

Other Common Oxidizable Materials. Hydrogen sulfide theoretically can be oxidized by chlorine to sulfite, or sulfate, the last-named representing usual practice when chlor-oxidation is employed. To remove one part H_2S requires about 8.5 parts* of chlorine; about 10 parts of alkalinity (as $CaCO_3$) are consumed by the reaction

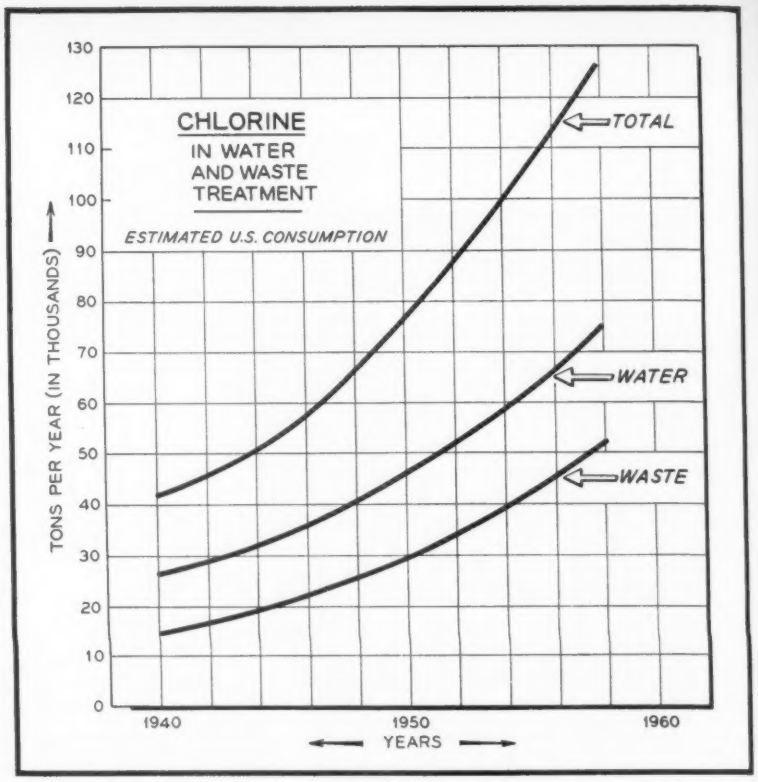

FIG. I-1. ESTIMATED use of chlorine for disinfection and other purposes at water and waste treatment facilities in the United States.

which occurs optimally at about pH 9.

Nitrites are occasionally found in some water supplies, particularly those contaminated by sewage and certain industrial wastes. Nitrites are readily oxidized by chlorine, especially free chlorine, to nitrates and HCl, each part of nitrate consuming about 1.5 parts of chlorine. These sources of chlorine demand also may be significant in adjusting the chlorine dosage to accomplish the desired objectives.

Ammonia and Amines. The reactions of chlorine with ammonia are of great signficance in chlorination of water, particularly in disinfection. When chlorine is added to water containing natural or added ammonia, a combined available chlorine residual (containing little or no free available chlorine) is obtained. The following equations suggest what might occur.

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$$
(monochloramine)

$$NH_3 + 2\,HOCl \rightarrow NHCl_2 + 2\,H_2O$$
(dichloramine)

$$NH_3 + 3\,HOCl \rightarrow NCl_3 + 3\,H_2O$$
(trichloramine or nitrogen trichloride)

$$2\,NH_3 + 3\,HOCl \rightarrow N_2 + 3\,H_2O + 3\,HCl$$

The chloramines are profoundly different in their bactericidal properties from free chlorine forms.

If sufficient chlorine is added, a point is reached where all ammonia is oxidized, substantially to nitrogen, and the chlorine itself is reduced in the process. Further additions of chlorine will then provide a residual of *free available chlorine* as HOCl or OCl^-. Below this point, chlorine residuals exist as *combined available chlorine*, consisting essentially of mono- and dichloramines in various proportions depending largely on pH (see Figs. I-4, 7).

Reactions analogous to those between chlorine and ammonia also occur to varying degrees with organic amino groups. While certain organic chloramine residual complexes do possess some bactericidal properties, they do not nearly compare in rate of bactericidal action with that of organic chloramine and free chlorine residuals.

Oxidizable Organic Substances. There are a great number of organic substances in waters that react with chlorine (and chloramines) at various

*A part can be a mg/L (ppm) or lb/mil gal or any other value as long as one unit of measurement is used throughout the relation or calculation.

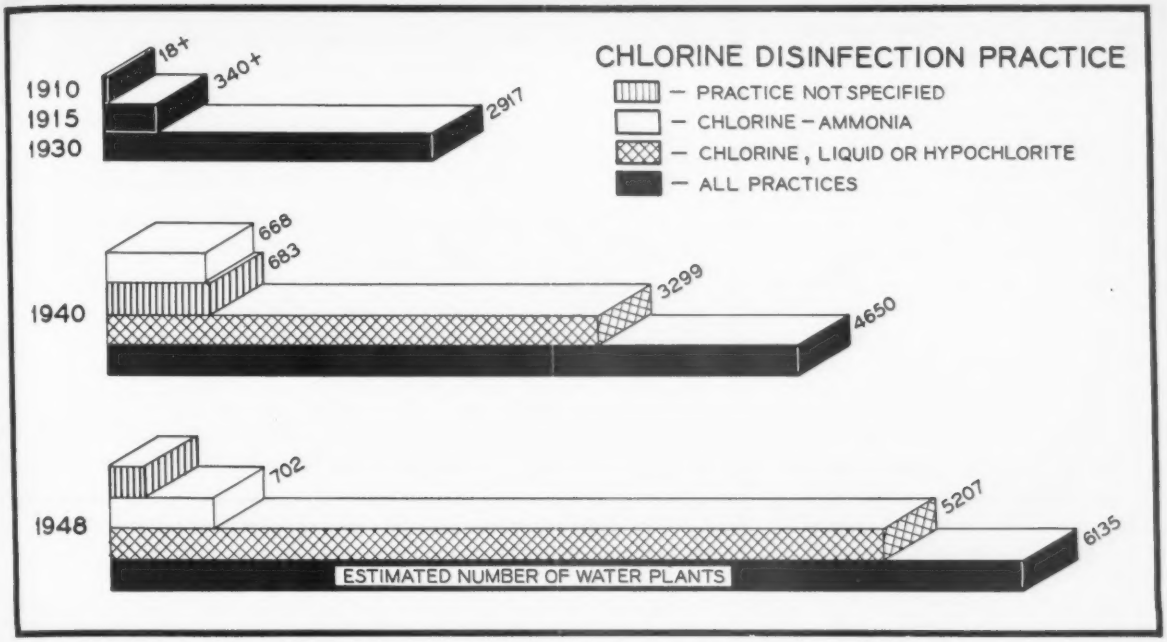

FIG. I-2. NUMBER of water plants and type of chlorine disinfection practice employed in the United States: 1910-1948 (From Statistical Summary of Water Supply Treatment in the U. S. by John R. Thoman. PHS Publ. 301, 1953.

rates and under various conditions. These may exert a substantial influence on the chlorine demand of the water, depending on chlorine concentrations and reaction time. (For this reason both variables should be specified in any definition of chlorine demand). When such conditions exist, chloro-addition and chloro-substitution products might be formed (some of which may exhibit some bactericidal properties), or the organic matter may be completely oxidized. Such considerations are important in establishing a chlorination regimen.

Bacteria and Other Organisms. As already noted, although chlorine as a chemical oxidant has considerable utility in water treatment processes, its primary use for disinfection is by far the most important.

Several theories have been advanced to explain the mechanism of bacterial destruction or inactivation by chlorine. The current belief is that death results from the action of chlorine on essential bacterial enzymes, particularly triosephosphate dehydrogenase. According to theory, hypochlorous acid (HOCl) exhibits greater ability to penetrate the cell membrane and to oxidize the essential enzyme(s) than hypochlorite (OCl^-) and other chlorine forms. Similarly, investigators suggest that monochloramines are less effective than dichloramines.

Two practical considerations become immediately apparent: first, the bactericidal efficiency of free chlorine is greatest when existing as HOCl and the more highly substituted chlorine derivatives of ammonia; and, second, spores and cysts—because of their resistance to penetration—are less susceptible to chlorine than vegetative bacterial forms. The first consideration can be properly dealt with largely by pH adjustment, while the second involves limitations not always fully compensated by adjustment of chlorine dosage and contact periods.

Chlorine Disinfection

Chlorine treatment has never been authoritatively advocated as a substitute for filtration and certain other unit water treatment processes. However, neither can the occasional claim be supported that filtration and sedimentation provide effective protection against bacterial pollution.

Fundamentally, to ensure freedom from pathogenic bacteria it is only necessary to provide a certain residual (excess of chlorine) at the end of a given period of time after chlorination. The character and magnitude of the residual, and the period of time, are largely reciprocally interdependent and depend on such factors as pH, temperature, organic pollution, and the presence of ammonia and other amino compounds capable of forming chloramine complexes. In general, low pH accelerates, low temperature retards, and the presence of ammonia, amino and other organic materials diminishes the bactericidal potential of available chlorine in either free or combined form.

pH. As indicated previously, solutions of chlorine gas in water tend to lower the pH and consume alkalinity. This does not apply in the case of hypochlorites that are alkaline and, in fact, actually tend to raise the pH slightly. It has been demonstrated that the efficiency of chlorine as a bactericide depends on how it exists, both in the free and combined forms: in the former, hypochlorous acid (existing predominately at pH 6 to 7.5), and in the latter, dichloramine (existing predominately at pH 4.4 to 6.5) are the most potent (see Fig. I-4).

It is apparent, then, in the pH range normal to most domestic water supply sources, that a reduction in the bactericidal potential of free chlorine and chloramines (especially) occurs at higher pH. While for some purposes it may be desirable to adjust the pH to an optimum level for disinfection, it might also be desirable to operate at a slightly higher pH as an adjunct to coagulation, for sulfide oxidation, corrosion control or other purposes.

Temperature. The bactericidal ca-

pacity of free chlorine and chloramines increases with rising temperature. Diminished rates of bacterial reductions are especially apparent when a combination of lowered temperature and high pH occurs.

Time. The resistivity to chlorine exhibited by bacteria and other organisms varies greatly. In addition to the above factors, whether chlorine exists as free chlorine or as chloramines, sufficient contact must be provided to effect complete destruction of all pathogens and other organisms of sanitary significance. Other conditions being the same, the time required for free chlorine forms is considerably less than that required for chloramines although the latter persist for much longer periods. It generally is considered that with the same amount of residual a contact time about 100 times as great is required for chloramines to accomplish equivalent bacterial kills.

Form of Available Chlorine. It is well established that combined available chlorine forms—principally the chloramines—are far less active than free available chlorine forms existing especially as hypochlorous acid. It has been suggested that the relatively low oxidation potential of chloramines accounts for this phenomenon. About 25 times as much chloramine as free chlorine is necessary to effect equivalent bacterial kills during the same contact period.

Free and Combined Chlorine

The type of available chlorine residual required and the characteristics of the water being treated determine the process of disinfection to be employed or maintained. All chlorination practice, irrespective of the point of application, may be classified as free available residual chlorination (i.e., breakpoint or super-chlorination) or combined residual chlorination, depending upon the nature of the chlorine residual formed. Both types, satisfactorily employed, will yield a safe water: from a practical viewpoint, however, both are not equally applicable to all water sources for disinfection or to enhance auxiliary objectives (see Fig. I-8).

Free Available Residual Chlorination. As previously noted chlorine reacts with ammonia and other impurities in water to form combined available chlorine forms.* If sufficient chlorine is added, the residual will exist almost exclusively as free available chlorine when ammonia is destroyed. The "point" of maximum chlorine demand, beyond which the residual rises in proportion to the

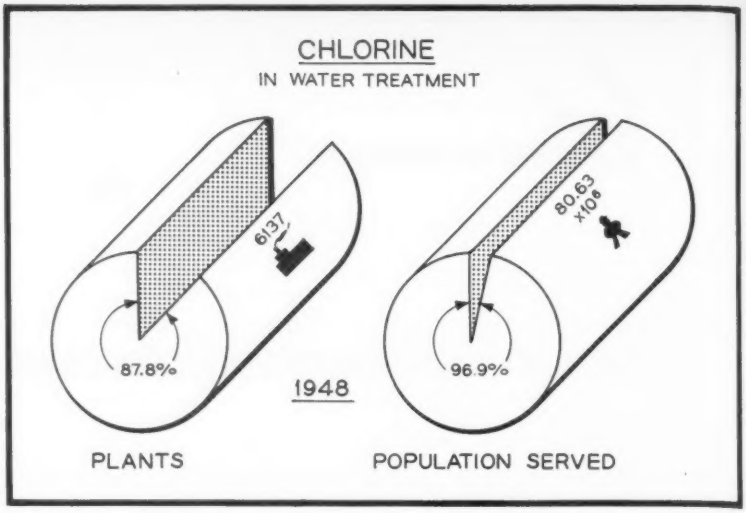

FIG. I—3. WATER TREATMENT plants in the U. S. employing chlorine disinfection in 1948 and estimated population served. (Source: Same as Fig. I-2.)

*The reaction of hypochlorous acid with ammonia is not instantaneous, the speed depending largely on the pH and temperature. Thus, for a short period after the addition of chlorine to a water containing ammonia, some free chlorine will exist and, until this has reacted to form chloramines, it will react with the vigor associated with free available chlorine forms. Thus, under these conditions the bacterial kill will be greater than that due to combined available chlorine to the extent that it is less affected by temperature, pH and relative ammonia-chlorine concentrations.

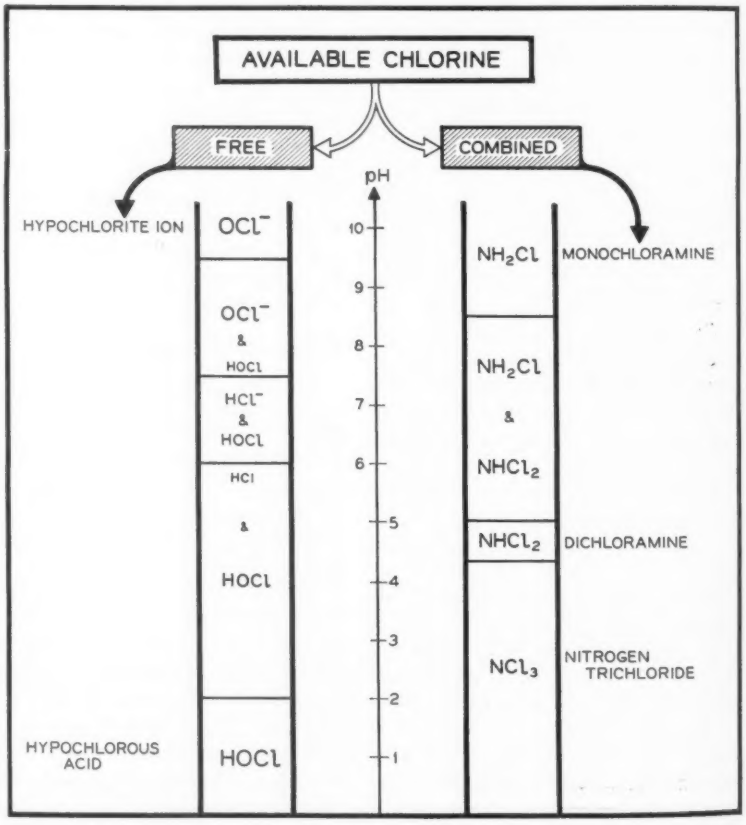

FIG. I—4. RELATIONSHIP of pH to free and combined forms of available chlorine.

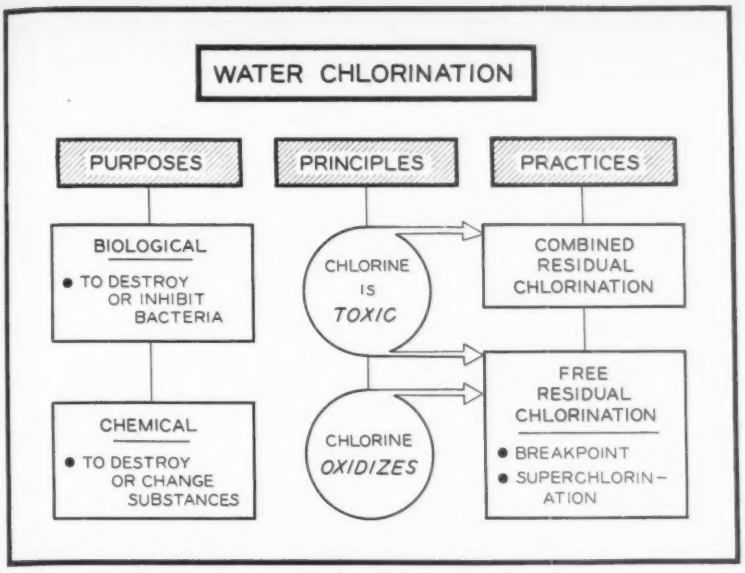

FIG. I-5. APPLICATION of chlorine in water treatment.

dose, is called the *breakpoint*. It is not absolutely essential that the breakpoint be reached to accomplish disinfection providing sufficient time is allowed for chloramines and other chlorine complexes to exert their effect.

Beyond the breakpoint, the chlorine dose (and form) usually is sufficient to satisfy the chlorine demand due to less-resistant bacterial forms and some easily oxidizable inorganic and organic constituents of the water, as well as to provide a slight residual of free chlorine to attack more resistant bacteria and other more complex chemical impurities. Moreover, the addition of substantial excess chlorine—the process of superchlorination—will result in further satisfaction of the chlorine demand and oxidation of organic complexes such as those that give rise to tastes, odors and colors. (Destruction of bacteria is, of course, rapid and complete when superchlorination dosages are employed.) Subsequent dechlorination usually is necessary to render the water palatable when superchlorination is practiced.

High free residual chlorination is especially indicated where the raw water quality is poor, for manganese (and sometimes iron) reduction, or when the contact time with marginal chlorine dosages is insufficient to effect disinfection. Moreover, it is useful where tastes exist before treatment and to destroy objectionable tastes due to substances that react with small quantities of chlorine (in contrast to strictly chlorinous tastes that can readily be removed by natural or artificial dechlorination).

Large doses of chlorine oxidize and destroy taste-producing substances, and breakpoint or superchlorination may be successful in taste control if water contains phenolic compounds, certain algae growths, etc. where other treatment is ineffective. The amount of chlorine required and, thus, the treatment process to be employed to break down odor producing bodies, depends on the type of intensity of pollution; 1 mg/L may be sufficient to reach the breakpoint in some waters, while others might require 10 mg/L of chlorine or more.

Combined Available Residual Chlorination. Combined available chlorine forms, principally inorganic chloramines, are effective for disinfection providing the concentration and exposure time are adequate. Unless bacteriological tests demonstrate otherwise, generally it is advisable to provide a minimum of 30 to 60 minutes contact before delivery to the consumer. Rapid disinfection cannot be expected but once effected, the residual will persist much longer than free available residual chlorine forms.

Unlike free residual chlorination, chlorine-ammonia treatment will not greatly alter tastes existing in the raw water (by oxidation), but it will offtimes prevent chloro-substitution tastes from forming. The process usually is effective, however, for controlling aftergrowths and reducing dead-end red water troubles in the distribution system, for providing a

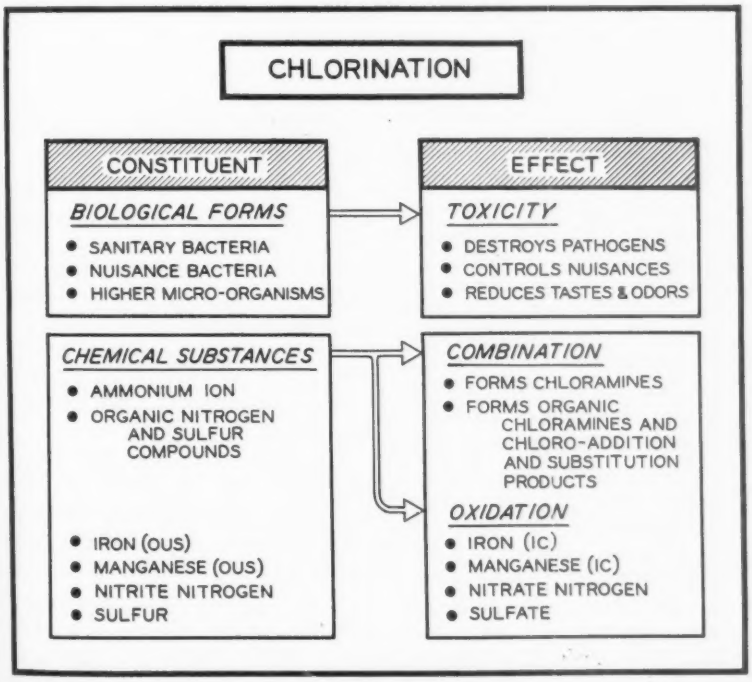

FIG. I-6. BIOLOGICAL and chemical effects of chlorine in water and waste treatment.

high, tasteless and effective residual at the point of consumption, and for control of certain algae forms. Where iron or manganese removal, color reduction, control or difficult taste and odor problems are specified, free residual chlorine treatment usually is more effective and economical.

Where chlorine-ammonia treatment is indicated, ammonia (generally as a gas, but also in aqueous form, or as a compound such as ammonium sulfate) may have to be added to some waters to obtain the desired effects. Since it is a critical constituent of the reaction, the concentration must be carefully controlled. In practice, about three parts of chlorine to one part of ammonia yields good results.

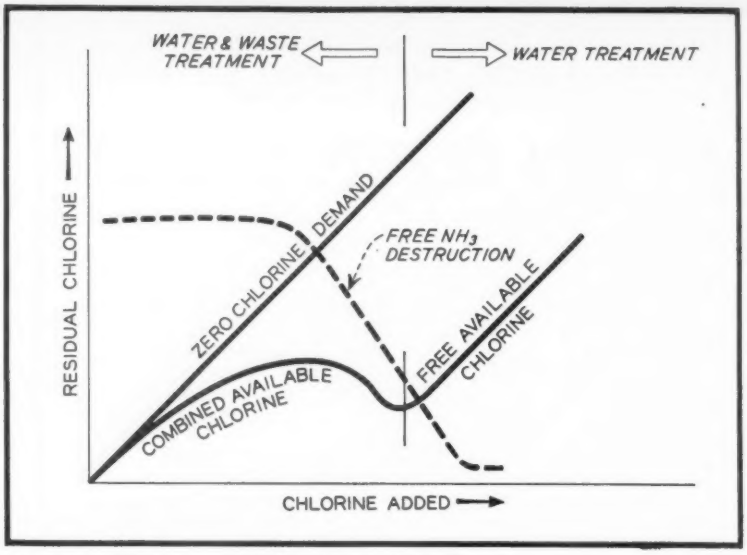

FIG. 1—7. FREE and combined residual chlorination.

Points of Chlorine Application

Although chlorination policy has been molded by experience into fairly well established channels, it is abundantly evident that chlorination practices are varied. Not only does this apply to combined and free residual chlorination practices, but also to the points at which chlorine is utilized in water and waste treatment systems. Basically, these depend on the specific objectives of chlorination, technical, practical, economic and other considerations.

When chlorination of water was first employed for disinfection, terminal treatment of the purification plant effluent was almost invariably practiced. Today, the use of chlorine in various stages of water treatment, and even in the distribution system, is common practice. Split chlorination schemes are increasingly employed for disinfection and other purposes, and frequently enhance the efficiency of many unit water treatment processes.

Pre-chlorination. Pre-chlorination is the application of chlorine to water prior to any other unit treatment process. Among the benefits claimed for the practice are: Improved filter operation by reduction and equalization of the bacterial and algae load, control of slime and mudball formation; improved coagulation; reduction of taste- odor- and color-producing materials by oxidation and retardation of decomposition (in settling units); and, importantly, the provision of a safety factor in disinfecting heavily contaminated waters while keeping the chlorine residual in the distribution system at a minimum. Chlorine treatment is not, however, the unfailing panacea for all these ills.

When pre-chlorination is indicated it is usually desirable to obtain a contact period as long as possible, preferably by adding the chlorine to the raw water suction intake and insuring its contact with water during the entire treatment process. The dosage, of course, depends on the objective. For example, if manganese oxidation is desired, free residual chlorine dosage is indicated; if decomposition retardation, removal of small amounts of color and iron, or use as a coagulant aid (e.g. activated silica) is the objective, combined chlorine forms may suffice.

Post-chlorination. Post-chlorination is the application of chlorine to water subsequent to any other unit treatment process. The most important form of post-chlorination is that following filtration for disinfection and to provide an active chlorine residual in a part or the entire potable water distribution system. The contact period provided to effect disinfection, as discussed elsewhere, is an important consideration; chlorine usually is added to the filter effluent or at the filter clear well.

Rechlorination. Rechlorination is the application of chlorine to water, following previous chlorination treatment, at one or more points in the distribution system. The practice is especially common where the distribution system is long and complex and where the effluent residual is insufficient to control biological growths, red-water troubles, etc.

Dechlorination. Superchlorinated water (as discussed) usually contains an esthetically objectionable excess of free available chlorine which must be removed before it is acceptable to consumers. Prolonged storage (especially in sunlight) and absorption on activated carbon are effective for this purpose. Also, such reducing compounds as sulfur dioxide, sodium thiosulfate and sodium bisulfite are frequently employed as dechlors. When sulfur dioxide is employed for this purpose (yielding HCl and H_2SO_4), about one part (by weight) is required for each part of chlorine to be removed.

Chlorine-Ammonia Treatment. Except where chlorine-ammonia treatment is employed to prevent tastes and odors being formed or increased in intensity during the various treatment processes, the general trend is to employ a split chlorination schedule, pre-chlorinating with chlorine alone, followed by chlorine-ammonia treatment after filtration.

The points of application of ammonia and chlorine should be sufficiently far apart to permit thorough mixing of the ammonia with the water before chlorine is applied, but not so great as to permit dissipation of ammonia by organic matter before chlorine is added. The prior addition of chlorine may result in the formation of chloro-substitution products un-

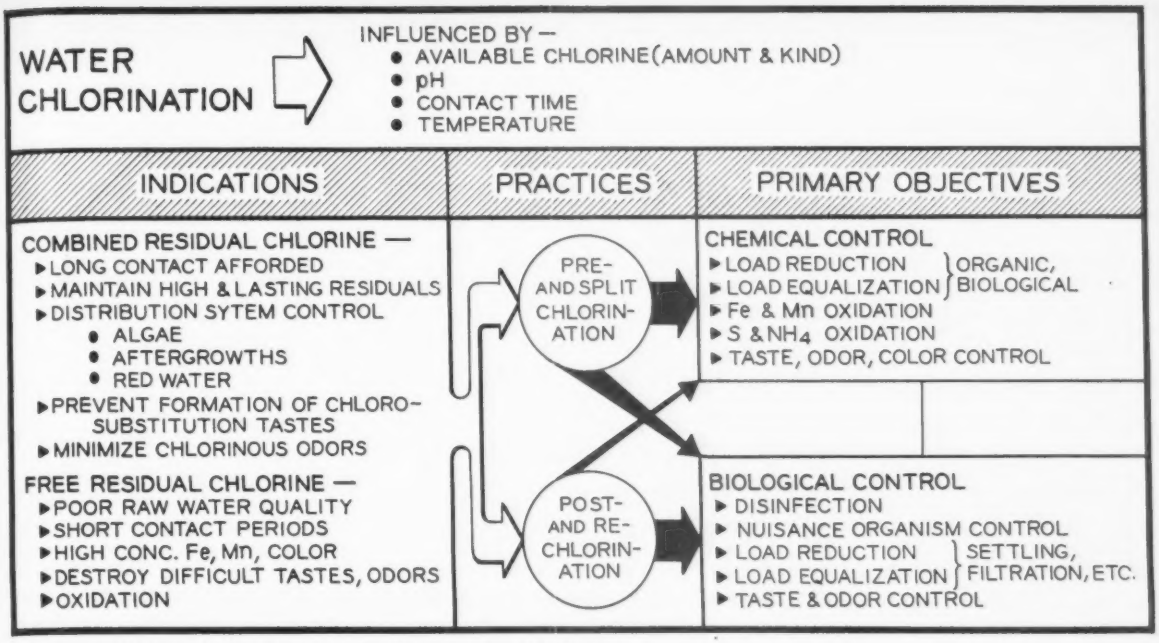

FIG. I-8. SUMMARY of principles of conventional water chlorination.

affected by chlorine-ammonia treatment.

Acknowledgment

Figures illustrating typical biological and chemical effects of chlorine in the treatment of water and wastes were developed from a concept suggested by Harry A. Faber, formerly research chemist of The Chlorine Institute, and presently Research Coordinator, Engineering Resources Program, Div. of San. Eng. Services, U. S. Pub. Health Service, Washington, D. C.

Regeneration of Ion-exchange Softeners

by PAUL C. ZIEMKE
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A storage tank should be arranged to receive dump truck lots through a cast iron manhole set in the concrete of the pavement, either inside or outside the plant. In some plants the hopper idea is used as the receiving point with distribution to elevated storage by endless chain conveyors, or rubber belt line. A brine storage tank may be on the same level as the receiving hopper or at some remote and elevated point where the pipe lines are extended to it. Brine is then either pumped to, or gravity fed to the process.

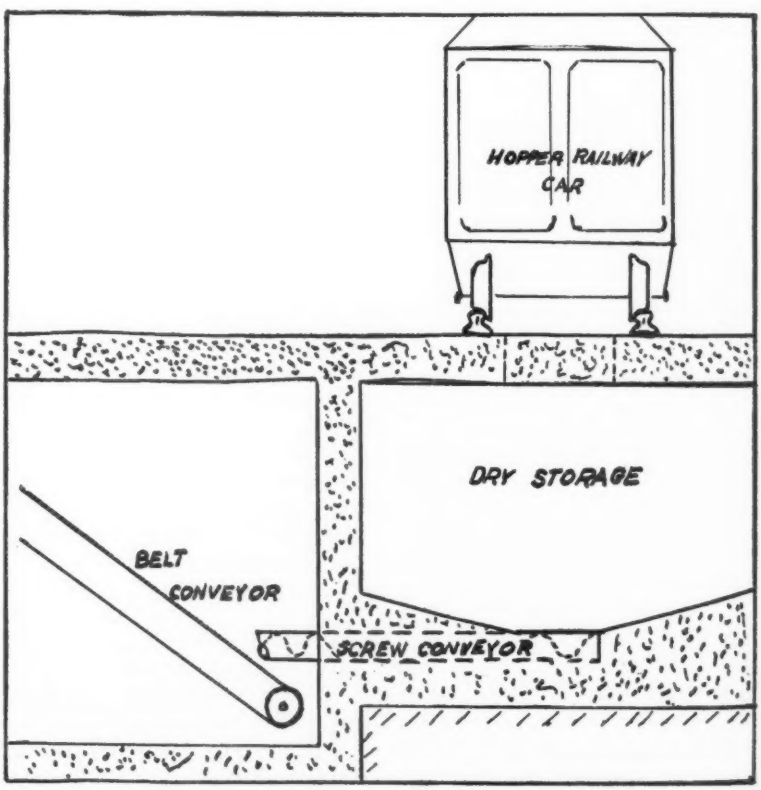
If desired, the receiving hopper can be used for a dual purpose, that of initial storage for the dry salt, and the brine that is developed as water is added. A phenomena about brine is that though the tank appears to be full still additional amounts of salt can be introduced into the seemingly fully saturated brine. The brine may then be pumped to any point in the plant with centrifugal pumps designed to handle slurry.

Undertrack Storage

One mid-western municipality having a water softening plant of considerable size in connection with its 1840 ft artesian supply has installed undertrack storage arranged beneath the spur laid by the railroad to receive hopper-bottom car shipments of salt. The accompanying sketch indicates an arrangement of this nature.

The high first cost of this installation was more than offset in the simplicity of the system that gets the salt unloaded and coverted to brine for the ion-exchange regeneration process.

Another plant using hopper-car-lots of salt has a dual-compartment storage arrangement where two separate dissolving compartments store an ample supply for daily requirements. The control room is located adjacent to the storage and dissolving chambers. Extra storage capacity is ample to tide over any delays that may occur in rail shipments. Purchases of bulk lots reduce the unit cost of material.



SALT in bulk quantities can be stored in concrete bins loaded from hopper-bottomed railroad cars and conveyed to solution tank by screw and belt conveyor systems.

Polyphosphate Treatment

by DAVIS E. SPEEG
Chemical Engineer Coastal Engineering Corp., New Orleans, La.

In 1833, Thomas Graham, a British chemist and the founder of the field of colloidal chemistry, discovered a new form of phosphate which he called sodium metaphosphate, one of the polyphosphates. It was known as Graham's salt for many years; and during the next eighty years, this chemical was confined to laboratory use. In 1929, Dr. Hall, of Hall Laboratories, and his co-worker, Mr. Jackson, first produced and used the sodium hexametaphosphate commercially for boiler water conditioning. Dr. Hall announced his discovery in 1932 of its properties of softening water without precipitation and without the removal of the hardness constituents. This led to a very intensive study of the metaphosphates and the properties of what later came to be known as the *Cinderella of the phosphates*.

It might be well to describe exactly what the polyphosphate is. By Webster's definition, *poly* is "a combining form meaning many or much; consisting of many; several; or more than the normal." You could more easily define polyphosphate by saying that it has by its nature, characteristics and chemical composition, or structural form, other than what is commonly known by the chemist as the normal phosphates, or orthophosphates. There is a pamphlet, "The Peculiar Phosphates—Some Suggestions Concerning Nomenclature," by Dr. E. P. Partridge of Hall Laboratories, that fully describes, as he terms it, this metaphosphate muddle.

Probably the most widely used polyphosphate today for water treating is the sodium hexametaphosphate. Therefore, an attempt will be made to list here some of the virtues, characteristics, and applications of this phosphate. Most of the literature research has been obtained from the files of Hall Laboratories and Calgon Company. "Calgon" is a trade name for a food grade hexametaphosphate.

Before discussing the properties of sodium hexametaphosphate, particular attention is directed to the exact control conditions, as regard pH and concentration, that are required to attain the optimum effects and results from the use of hexametaphosphate. This material is certainly not a cure-all, nor is it advertised as such. It does have properties, however, that make its application very attractive to many conditions that exist in the municipal water treating field. The useful life of sodium hexametaphosphate is a function of time, temperature, and pH. A technical bulletin entitled, "The Useful Life of Pyro, Meta, and Tetra Phosphates," by Morgen and Swoope, University of Florida, gives a full description of the useful life of these phosphates. With respect to its chemical and physical acting properties, sodium hexametaphosphate has two properties:

1. A definite surface active property at the solid aequeous innerfaces.
2. The property of forming soluble complexes with multi-valent cations, thereby removing them from their normal chemical action, appearance, or function.

By these two chemical and physical characteristics, the following properties of sodium hexametaphosphate may be applicable to the municipal field—namely:

1. Dispersion.
2. Threshold Application.
3. Sequestration.
4. Affinity for the Formation of Metal Complexes.

Each of these will be discussed individually.

Dispersion

A dispersion signifies the state of suspension of finely divided particles in some other substance. By Webster's definition, to disperse means "to break apart and go different ways; to scatter or to cause to become widely separated." Some common dispersions are paints, certain textile coatings, milk of magnesia, laundry starch, mayonnaise, and more common to us, oil well drilling muds. It has been found that by the application of sodium hexametaphosphate at a concentration of 2,000 to 4,000 mg/L, you

are able to widely disperse most substances found in fresh water wells. Sodium hexametaphosphate has been widely marketed to restore the capacity of water wells. In essence, what this hexametaphosphate does is to disperse and lift to the surface fine silt and iron deposits commonly found in wells. Most of the well drillers, as well as many of the municipal superintendents, in the nation use this material to restore wells.

Hexametaphosphate is used, also, as a dispersive for treatment of drilling muds for oil production. This was particularly true several years ago, prior to the advocation of the high pH muds and before the extreme depths that are being drilled today. It can be well appreciated that with the increased depth there is also an increase in temperature. The reversion of the metaphosphate in the presence of the high pH and high temperature make its useful life very short. It is used very widely today, however, for the *surface hole*.

The cleaning of zeolite and all purpose filters with sodium hexametaphosphate is quite common. This application would be one of dispersive. Some of the zeolites and filters become coated with "mud balls" or amorphous precipitants of iron. These may be easily dispersed, broken up, and removed from the beds, giving a very effectively cleaned resin or filter bed. It is not, however, advocated to use sodium hexametaphosphate to use this method to cleanse filters that are coated with a calcium carbonate precipitant. It is known, however, that the sodium hexametaphosphate will prevent this precipitation under different concentrations and control conditions.

Threshold Application

The properties of threshold application of sodium hexametaphosphate to the municipal field are oftentimes misleading and misconstrued. The threshold application as pertains to scale prevention is the application of 1-2 mg/L of hexametaphosphate to a scaling water, thereby preventing the crystalline growth of calcium carbonate particles to build scale. Growth of this nature also occurs very often on filter sand and is commonly referred to as filter growth. The sharp edges of the filter sand are coated with the deposit, thereby reducing the filtering efficiency of the bed.

The threshold application of CALGON in red water removal is really the same application of hexametaphosphate involving the ions of iron and manganese instead of calcium. Quite often, however, in a low pH water dissolved iron will be present. As soon as this is exposed to air or chlorine, the iron will precipitate, forming a so-called red water. These waters are normally high in carbon dioxide and are very corrosive by nature. The application of a hexametaphosphate in a magnitude of 2-4 mg/L for each mg/L of dissolved iron can prevent this red water appearance. In essence, what has been accomplished is the precipitated iron particle is prevented from growing, so to speak. The iron will not precipitate visually. The test can be made for the iron, and will be found to be present. However, its character of red water will be eliminated. Hexametaphosphate in the system also will form a protective film in the pipeline, thereby preventing the further dissolving of iron by setting down a protective phosphate film. This application is a property to be described later. Most of the applications depend upon the individual problems of water supply. The control conditions for each application are as follows:

1. Scale Prevention: 1-2 mg/L hexametaphosphate applied to the effluent of the clarifier to attain maximum protection, i.e., the filter bed as well as the lines and valves.

2. Iron and Manganese Stabilization: 2-4 mg/L hexametaphosphate for each ppm of iron. If manganese is present, lend toward the high dosages. It is imperative that the hexametaphosphate be added *before* any chlorine is added and prior to being exposed to the atmosphere. The oxygen and the chlorine would both oxidize the iron, causing it to precipitate. The hexametaphosphate would be of little use at this stage of application.

Sequestration

The term *sequestration* means "the act of retiring, secluding, or withdrawing; the act of taking possession of or confiscating." To sequester would be to remove certain properties that would normally exist. To a chemist, the application of hexametaphosphate for sequestration would be known as a stoichiometric reaction. In other words, the amount of hexametaphosphate needed would be directly proportioned to the amount of metallic ion present in the existing system. This application in municipal fields is pertinent primarily to those where the hard water is completely softened by sequestration—such as, laundering. This property would, also, apply to those municipalities that are engaged in operating boilers for the production of steam. The phosphate ion in this instance ties up the calcium and magnesium ion, rendering them relatively inactive insofar as forming scales of silicate, sulphate, or carbonate. This property may be easily demonstrated, and quite effectively, by taking a garment that has been washed, rinsed and dried, and rinse it again in a water that has a high concentration of sodium hexametaphosphate. It will be noted immediately that a sudsing action will appear. This is because the precipitated soap scum that is prevalent in all washes redissolves in the hexametaphosphate treated rinse water.

The properties of sequestration are, also, carried into the industrial field. Sodium hexametaphosphate exercises a peptizing effect and dispersing action on many heavy metals and oxides. In the dyeing of papers and cloths, it is very important that the dye water be calcium and magnesium free. Hexametaphosphate is used to sequester any possible calcium and magnesium ions that might find their way into the system. The same is true for the textile industry. The leather tanning industry was greatly revolutionized with the increased rate of penetration of tannins into leather through the use of hexametaphosphates.

Affinity for the Formation of Metal Complexes

This property of hexametaphosphate falls under two categories:

1. The Treshold Application for Corrosion Control, which is the formation of an iron metaphosphate film barrier, is applicable when metaphosphate is applied at the rate of 2-4 mg/L under pH controls of above 7.0. This is commonly known

as the threshold range for corrosion control. The application has been recently supplemented by new and better methods of protection.

2. The Affinity for Metal Protection is much more effective in what is called the low pH-high metaphosphate range. This is where the pH of a water system is dropped to 6.0-7.0 and a metaphosphate residual of 10-15 mg/L is maintained. This application of metaphosphate is rare among most municipal operators except those operating power plants where cooling towers are involved. It is in common use at industrial plants, such as refineries and chemical plants where large cooling towers are operated. It has been found to be one of the most effective methods of protecting ferrous systems where scale-forming waters are used.

New Advancement in Polyphosphate

There have been two very recent advancements in the use of polyphosphate. The most recent advancement is probably the Calgon TG. This is like standard Calgon in that it is a colorless glass platelet, but instead of a straight sodium hexametaphosphate, it is now a sodium zinc hexametaphosphate. It has some decided advantages over standard sodium hexametaphosphate in that it has:

1. More rapid film formation.
2. More efficient corrosion protection.
3. Less reversion.
4. Ease of feeding.

Many waters of various types have a much more rapid film formation with the Calgon TG, due to the synergistic effect from the presence of zinc. A more efficient corrosion protection is attained due to the formation of a tougher film which is set down more quickly. This means that superior results can be obtained at an equal rate of feed or possibly even at 30-40 per cent reduction in the rate of feed. Since the metaphosphate is really the active character in this treatment, the effective treatment can be prolonged by reducing the reversion rate. Calgon TG is very effective at municipal water works where a fast film formation is desired, particularly after main line cleaning, or in very corrosive waters such as those extremely high in carbon dioxide.

Another recent advancement in the use of polyphosphate for water treating is what one company has termed *controlled solubility*. The feeding of metaphosphate in many installations does present a problem. Some want a very highly soluble material such as straight sodium hexametaphosphate, whereas others wish a material of a slow-dissolving character that can be suspended from cooling towers, basins, or fed through various pot type feeders—with the intent to charge baskets and pot feeders every two weeks or even as much as once per month or once per season. Each of these materials is marketed under various trade names, such as Calgon 15-J, Micromet, and so forth each designating a "half-life" or "quarter life" solubility, meaning that for a pre-determined time one-quarter of the charge will be dissolved or one-half of the charge will be dissolved. In essence, it is merely a feeding method for the same familiar *Cinderella phosphates*, the hexametaphosphates. The application of these controlled soluble hexametaphosphates varies from the cooling towers atop office buildings to the fracturing of sands thousands of feet into the earth.

More recent advances in the use of polyphosphate, and here again water is involved, is found in the use of sodium hexametaphosphate in the meat packing industry. This Cinderella of the phosphates has allowed the packer to produce hams of higher yield weights, redder color, tastier, with shorter cook-out time; and in the production of bologna, the reduction of "fat-capping" has been tremendous. Some of the new advancements in polyphosphate usage have been extended to the canneries and preserving industries. In the preserving industry, the color retention of fruit has been greatly preserved. The browning of fruit, such as peaches, has been attained. In the canning industry, the color retention of green vegetables has been improved, as well as the shrinkage of things such as peas and beans. This is achieved by the sequestration of the calcium ion which does cause a shrinking in peas, as well as the stabilizing of iron, which would cause discoloration.

It should be emphasized that hexametaphosphate is not a cure-all but by the application of the three mentioned properties, it can be used to attain remarkable results that oftentimes seem to be insurmountable. Although the properties above described have been proven many times, hexametaphosphates should only be applied under controlled conditions if the optimum results are to be attained. There are exceptions to each property. Therefore, the use of this material should be evaluated by technical people versed in its applications and the indiscriminate use of hexametaphosphate should be avoided.

Synthetic Detergents as a Factor

Water Softening Economics

by WILLIAM W. AULTMAN

Vice-Pres., James M. Montgomery, Cons. Engr., Pasadena, Calif.

Before the advent and widespread use of synthetic detergents for household cleansing purposes, several authorities[1-6] had demonstrated that the savings realized by the individual householder from the use of soft water were materially greater than the cost of municipally softening hard water. The major item used in the comparative evaluation was the cost of soap. Its required use varies directly with the hardness of the water, and soap is the one soft-water benefit to which a dollar value can be readily assigned. It is a question, however, whether these economic advantages still prevail now that the synthetic detergents are rapidly replacing soaps as cleansing agents in the home.

The definition of a hard or a soft water is not precise. A recently published textbook[7] uses a definition generally accepted by water authorities:

> Waters containing less than 50 mg/l of hardness are considered soft; those containing more than 100-150 mg/l, the magnitude depending upon the regional composition of available water supplies, are considered hard.

Municipal treatment plants seldom soften a water to less than about 85-100 ppm because water that is much softer than this has several disadvantages: It does not rinse away suds readily, may seem slippery, and may be quite corrosive. Moreover, a large percentage of the supply is used for lawn and garden sprinkling, toilet flushing, and other purposes where the hardness is not a concern.

Detergents are cleansing aids, soap being one of the oldest and best-known detergents. The newer types of "soapless soaps" are called synthetic detergents or "syndets." A soap is a sodium or potassium salt of a fatty acid, made by combining an alkali with a fat; syndets are complex chemical compounds made from petroleum, fats, or oils. Builders may be added to soaps and syndets to give them greater cleaning power or to give them some water-conditioning properties, or both. These builders are alkalies such as carbonates, silicates, and phosphates[8].

Syndets

The major item stressed in the publicity for the syndets has been that they perform just as satisfactorily in hard water as in soft. This is not correct; it is this statement that has led to the belief that water softening is no longer needed.

The effect of hard water on detergent use is recognized by the chemists who manufacture syndets, as shown by a statement in a recent technical article on the subject[9]:

> One virtue of synthetic detergents is that, in general, they give very soluble calcium and magnesium salts. It was expected that the detergency of synthetic detergents would not be adversely affected by hard water. However, the shift from soap to synthetic detergents did not entirely eliminate the hard water problem. Detergents provided only an apparent, partial solution by not forming insoluble hard water salts. Later, it was found that the addition of phosphate to synthetic detergents was necessary for acceptable detergency in hard water.

The phosphate is added as a sequestering agent: the harder the water, the more phosphate required.

The amount of soap required to accomplish satisfactory cleansing in waters of different hardness can be ascertained readily, because soap does not clean until a lather is formed, and a lather does not form until the soap has reacted with the calcium and magnesium in the water. This reaction is what forms the "curd" when soap is used in hard water. The syndets do not react in the same way. Syndets dissolve readily in water which is hot or cold, soft or hard, and they do not form a "curd" in hard water. Their pronounced ability to emulsify oil and grease is an advantage in cleaning clothes. Some syndets form suds readily just as soap does, whereas others clean with little or no suds. The quantity of suds produced is not indicative of cleansing ability and frequently more suds are produced in hard water than in soft. Consequently, it has been difficult to evaluate comparatively the cleansing properties of the syndets in waters of differing hardness, or even the properties of the many different syndet formulations.

The method that has been developed for syndet evaluation is to ascertain the "per cent soil removal" from so-called standard, soiled cloth under different test conditions. This method has been fairly satisfactory, but is not truly representative of normal household washday conditions, for there are many different types of soil and it has been found that some syndets work very well with some kinds of soil and not so well with others. The chemists are, therefore, reluctant to release any comparative-evaluation data because a satisfactory standard of comparison has not yet been established.

An investigation which has included: [1] a survey of the technical literature, [2] correspondence with manufacturing and research chemists from the major producers of household syndets and private and governmental research technicians, and [3] personal interviews, has shown conclusively that water hardness does affect the efficiency of the syndets used in the home. This is borne out by such statements as:

> 1. Practically, all synthetic-detergent laundering products on the market today contain a soil-suspending agent. This agent is designed to prevent the redeposition of removed soil onto the fabric being laundered. These agents are good but not perfect. In the case of hard water, the magnesium and calcium ions present aggravate redeposition of soil, and it is for this reason that the detergents do not perform

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quite as well in hard water as in soft. As might be expected, this situation becomes worse as the hardness of the water increases[10].

2. Unfortunately, detergents are not the complete answer. At first, they go right to work on the dirt, breaking it up and floating it away. But hardness ions in the water interfere with these tiny particles and cause some of the dirt to be redeposited on the fabric. Although the hard water rinse can carry away the floating particles, it can't budge the redeposited dirt. The real answer is soft water to begin with, for both soap and detergent[11].

3. For similar cleaning jobs, however, a greater amount of synthetic detergent is needed in hard water than in soft[12].

4. Assuming average conditions—meaning about 7 grains hardness, moderate soil, and a 6-8 lb-load of clothes—we feel that a 0.2 per cent concentration of detergent will give satisfactory results and is a realistic concentration toward which to aspire. In soft water with all other conditions equivalent, 0.15 per cent concentration would probably give equal cleaning; and in 21-grain hardness, again all other conditions equivalent, probably 0.3 per cent concentration would be required for equal cleaning[13].

5. In washing clothes in a washing machine, it take approximately twice as much product in water, 21 grains per gallon (360 ppm) in hard as in soft water. The amount of product involved is approximately one normal-size carton of all-purpose detergent (20-22 oz) per week for an average family using water 7-10 grains per gallon (120-170 ppm) hard . . . You probably will not be far off if you assume that softening fairly hard water would save the average family one-third to one-half a carton of detergent (popular size, 20-22 oz) per week[14].

Soap vs. Syndets

The best specific, factual data presently available pertaining to the relative amounts of syndets and soaps required in hard and soft water were obtained by a cooperative study made in 1955 for the Dow Chemical Co. and the magazine, *Woman's Home Companion*[15, 16]. This study was made by the Warren family of West Lafayette, Ind., under the supervision of Purdue University. Under closely controlled conditions this family of five operated for four 6-week periods as follows:

1. First 6-week period using hard water (360-419 ppm) with syndets as principal cleansing agents
2. Second 6-week period using hard water (360-410 ppm) with soap as principal cleansing agent
3. Third 6-week period using soft water (zero-10 ppm) with syndets as principal cleansing agents
4. Fourth 6-week period using soft water (zero-10 ppm) with soap as principal cleansing agent.

The results of this study with respect to the use of soap and syndets are summarized in Table 1 and are shown graphically in Fig. 1. The same types of shampoo, toilet bar soap, dishwasher water conditioner, and scouring powder were used during all test periods. In 1955, when these tests were made, the syndet-type bar soaps were not so available as they are at present (Apr. 1958).

These data show that a larger quantity of syndets and soap are required to obtain proper cleansing in hard water than in soft water. They also show that the relative quantity of syndets required in hard water is proportionately not so great as the quantity of soap required.

At the start of each test period the Warren family was supplied with new dish towels, children's T-shirts and trunks, men's white shirts and bedding. Other items furnished were glass double boilers, tea kettles, glassware, and silverware. During the 6 months of the study Mrs. Warren, besides reporting cash expenditures, recorded the time required for the various household tasks and noted the appearance of the family clothing, linen, china, glassware, and silverware. She found that she saved time, effort, and money when she used soft water. A pictorial record showed clearly the improved appearance of the articles washed in soft water over those washed in hard water.

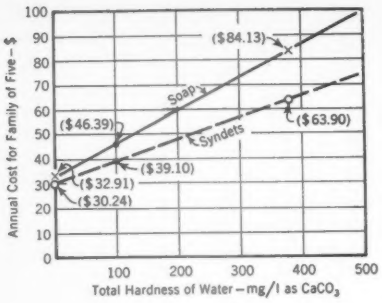
No attempt was made in this study to determine the effect of the hard or soft water on the plumbing fixtures and piping. An examination of the photographs of the teakettles and double boilers would indicate, however, that with the hard water, the hot water heater would tend to scale rapidly and thereby lose its heat-transfer efficiency in a short time. This would increase the cost of operation appreciably.

The development of various types of syndets for specific and general purposes continues. It is not known what the future may bring in the way of new and better syndets that might provide good cleaning properties for all materials and be less affected by the hardness of the water supply. With present knowledge, however, it appears that builders will continue to be required as additives to syndets to compensate for increased water hardness, and that the cost of cleaning when using hard water will continue to be greater than when using soft water.

Table I
Consumption of Cleansing Agents in Hard versus Soft Water

Use	Hard Water Period: Amount Used in 6-week Test Period oz	Hard Water Period: Amount Used in 1 Year oz	Soft Water Period: Amount Used in 6-week Test Period oz	Soft Water Period: Amount Used in 1 Year oz	Annual Difference: Quantity oz	Annual Difference: Unit Price $/oz	Annual Difference: Annual Cost $
Syndets							
Dishes, hand	36.00	312.00	5.00	53.00	269.00	0.01526	4.10
Laundry, machine	138.00	1196.00	52.00	450.00	746.00	0.01400	10.44
Laundry hand	6.00	52.00	1.33	11.50	40.50	0.01611	0.65
Cleaning	40.00	347.00	14.00	121.00	226.00	0.01526	3.45
Shampoo	3.44*	14.90	2.44*	10.60	4.30	0.30800	1.33
Shampoo	15.00*	65.00	9.40*	40.70	24.30	0.14285	3.48
Bar	21.75†	94.20	13.00†	56.30	37.90	0.13500‡	5.12
Dishwasher	92.50*	400.80	37.00*	160.30	240.50	0.01958	4.70
Scouring	47.00*	203.70	37.00*	160.30	43.40	0.00890	0.38
Annual cost		$63.90		$30.24			$33.66
Soaps							
Dishes, hand	38.25	331.50	3.75	32.50	299.00	0.02274	6.80
Laundry, machine	303.00	2626.00	77.00	667.00	1959.00	0.01366	26.75
Laundry, hand	7.50	65.00	1.50	13.00	52.00	0.02320	1.21
Cleaning	27.00	234.00	14.00	121.00	113.00	0.01260	1.43
Shampoo	3.44*	14.90	2.44*	10.60	4.30	0.30800	1.33
Shampoo	15.00*	65.00	9.40*	40.70	24.30	0.14285	3.48
Bar	21.75†	94.20	13.00†	56.30	37.00	0.13500‡	5.12
Dishwasher	92.50*	400.80	37.00*	160.30	240.50	0.01958	4.71
Scouring	47.00*	203.70	37.00*	160.30	43.40	0.00890	0.38
Annual cost		$84.13		$32.91			$51.22

* 12-week period
† Bars of soap in 12-week period.
‡ Unit price per bar.



Cost of Water Softening

The cost of water softening must be established before it can be determined whether, with the advent of the syndets, softening continues to be economically desirable.

Studies made and reported by T. E. Larson of the Illinois State Water Survey have established the relative cost of softening water in municipal treatment plants and by home-owned and home-serviced softeners[5, 17]. These studies also show the corresponding relative cost of soap to accomplish the same degree of softening. It is shown that municipal treatment seldom softens water to a total hardness of less than 85 ppm, while both the home-owned and home-serviced units soften the water to a nominal hardness of zero.

The relative costs, as developed by T. E. Larson, are shown in Table 2. Based upon the smallest cost reported, which is for salt for softening 85-ppm hardness water in home-owned units, the relative costs of the other methods or degrees of hardness are shown as a ratio to this smallest cost. An examination of this table shows that municipal softening is the cheapest, even when further softening to practically zero hardness is done by household-type softeners.

Table 2
Comparative Costs of Softening Methods*

Method	Initial Hardness—ppm			
	85	250	340	510
Municipal (to 85 mg/l)		2.0	2.7	4.0
Home-owned (salt cost)	1.0	3.0	4.0	5.7
Home-serviced	10.0	17.5	23.0	34.0
Soap	2.6	5.8	7.6	10.8

*Shown as ratio to lowest cost per given unit of water volume.
†Not including amortization of softener.

The results of a survey by one of the soft-water service companies on the distribution of installations of the rental type of unit are shown in Table 3[17]. The data in this table show clearly that municipally softened water would benefit those with low and medium incomes more than those with high incomes, because 90 per cent of those with high incomes presently receive soft-water service. The soft-water service companies and their customers would also benefit from municipal softening. Not only is the major portion of the hardness removed in the municipal plant, but also any iron, manganese, turbidity, color, and odors are generally removed.

The cost of water softened in a municipal treatment plant is variable, depending upon the type of hardness present—carbonate or noncarbonate—cost of chemicals, operating costs, interest charges, amortization of the capital investment, and size and type of treatment plant.

The cost properly chargeable to softening would be materially different for: [1] water requiring coagulation and filtration in any event, with softening added as a refinement; and [2] clear, iron-, manganese-, color-, and odor-free well water that would normally not be filtered except in conjunction with the softening process. In the first case, only the softening chemicals and a small amount of additional plant operation and facilities required for softening should be charged to the cost of softening. In the second case, all chemicals and all plant operation, including interest and amortization, should be charged to the cost of softening. In the first case, the cost of softening would normally be less than 3 cents per 1,000 gal. In the second case, the cost would normally range from something less than 6 cents to possibly 10 cents or more per 1,000 gal, depending upon the type of treatment and the type and capacity of the softening plant. The cost of construction of a large treatment plant is less per million gallons of capacity than for a small-capacity plant. A charge of 7 cents per 1,000 gal should be ample to cover all costs of softening in a plant of 30-mgd or greater capacity when reducing the total hardness of the water from about 380 ppm to about 100 ppm.

Table 3
Distribution of Dental-Type Softening Units

Annual Buying Income	Spending Units %	Rental-type Softeners Installed %	Families in Bracket Receiving Soft-Water Service %
Greater than $7,000	6	27	90
$2,000-$7,000	64	57	18
Less than $2,000	30	16	11

The reasonableness, and probable conservatism, of this assumption of a treatment cost of 7 cents per 1,000 gal, has been confirmed by: [1] a detailed estimate of the theoretical cost of plant construction and operation, [2] an analysis of the operating data from 86 treatment plants where the water is being softened[18], [3] a comparison with the total treatment costs as developed in a recent study[19], and [4] a comparison with the actual annual cost of operation of a large softening and filtration plant.

The average charge made (total revenues divided by total water sales) for the water delivered in the 86 communities where softening was reported in 1955 was 21.5 cents per 1,000 gal. This included all costs for production, softening, distribution, accounting and billing, administration, capital charges, new construction, and surplus. The systems reported ranged in water deliveries for 1955 from less than 1 to 180 mgd; the average was less than 15 mgd. The hardness of the water, natural and softened, was not reported, but would vary considerably. Analyses have shown that in municipal water service the costs for pumping, distribution, accounting and billing, administration, capital charges, and surplus are generally at least 75 per cent of the total revenues received. On this basis, the cost of softening would average not more than about 5.4 cents per 1,000 gal for the 86 communities reported.

The data compiled by Orlob and Lindorf[19] show that the total cost of treatment in the California area for a 30-mgd plant is approximately 4 cents per 1,000 gal. The type of treatment is not defined, but is assumed to be coagulation, sedimentation, and filtration only. The additional cost for softening chemicals and facilities would not exceed 3 cents per 1,000 gal, making an indicated total cost of not more than 7 cents per 1,000 gal.

The actual costs of operation of the

200-mgd water softening and filtration plant of the Metropolitan Water District of Southern California, located at LaVerne, Calif., are shown in Table 4. The salt for regeneration of the zeolite at this plant was purchased in 1955-56 at an unusually low price of $5.30 per ton delivered. If this cost were doubled, which would bring it to about the normal price for such sale elsewhere, the unit costs in Table 4 would be increased 0.878 cent per 1,000 gal to a total unit cost of softening of 3.668 cents per 1,000 gal.

It appears evident, therefore, that the assumed costs for softening in a municipal plant of 3-7 cents per 1,000 gal are reasonable averages to use for computation. (The lower figure applies only when treatment facilities are required to produce a satisfactory water even without softening.)

Table 4
Description and Operating Costs of Softening and Filtration Plant Metropolitan Water District of Southern California

Design capacity:	200 mgd
Type:	lime-zeolite softening and filtration
Total cost of plant*:	$7,662,980
Method of financing:	50-year bonds at 4% interest
Total water softened, 1955-56:	55,600 mil gal; average, 152 mgd
Average hardness reduction, 1955-56:	220 mg/l(natural water, 361 mg/l, finished water, 141 mg/l†)

Items	Operating Costs	
	Per Year—$	Per 1,000 gal—cents
Chemicals, power, waste water	794,284	1.426
Operation and maintenance	306,692	0.551
Employees' retirement	14,632	0.026
Total operating cost	1,115,608	2.003
Interest and amortization	356,712	0.641
Reserve for replacement	81,081	0.146
Total cost of softening	1,553,401	2,790

† Normal softened water hardness is 125 mg/l. Higher annual average is the result of operating the plant in the summer as much as 67 per cent above its designed capacity.
* Exclusive of land.

Residential Water Consumption

The total amount of water consumed by a family will vary greatly depending upon the size of the family, geographical location of the home, size of lot and type of landscaping, season of the year, and general standard of living of the family. Statistical studies made by the US Bureau of Census[20] show that there are approximately 3.5 persons per household on the average in the United States. Another study[18] shows that the average (median) residential water use in 86 cities in the United States served by publicly owned utilities was 68,000 gal per year per family in 1955. (These are not the same 86 communities used in the study of softening costs.) Based upon the household size of 3.5 persons per family, this average residential water use would amount to 53 gpcd. This figure agrees quite well with the per capita use reported in special studies made in the Illinois area[21, 22]. In the far west and southwest water consumption generally is considerably higher than in the Illinois area because of the warmer climate, the larger landscaped areas around the homes, and the low summer rainfall. In Los Angeles residential water use only, apart from all other uses, amounted to 122 gpcd in 1956-57[23]. Actual water-meter record analysis of the residential use in other Southern California communities indicates that the per capita water consumption is even higher in certain localities.

Economic Aspects of Softening

Special investigations were made by the Purdue University Experiment Station and the Michigan State Department of Health to determine what drawbacks there were, if any, to the use of hard water in the home which the use of syndets cannot overcome[2]. Estimated national averages based on the results of these investigations indicate that:

1. A 25 per cent saving is realized on fuel for heating soft water by eliminating deposits of scale which retard heat flow.
2. An 18 per cent saving on repairing, cleaning, and replacing plumbing that is caked with scale is realized.
3. Fabrics show 25 per cent less wear and tear in soft water.
4. Soft water saves 16 per cent wear and tear on utensils.
5. Food cooked in soft water retains its natural color and appearance, and its digestive qualities. In making tea and coffee it takes 50 per cent less leaves or grounds in soft water than in hard.
6. Soft water for skin care provides less possibility for skin dryness and irritation. Bathtubs do not develop the severe "bathtub ring" and expensive bubble bath preparations are unnecessary. Toilet bars, which are still largely soaps, do not cause lime soap deposits that must be removed by scouring powder and scrubbing. Shaving blades last 20 per cent longer.

These percentages and favorable results will vary with the actual degree of hardness of the water. These results are for water approaching zero hardness, which is the quality of water obtained from the individual household water softener or from rental-type, home-service units. Municipally softened water with a total hardness of 85-100 ppm is still, comparatively, many times better than natural water with 300-500 ppm hardness before treatment.

It is difficult, if not impossible, to attach a dollar value to many of the savings which are a result of water softening but the savings definitely exist, and the total is of considerable magnitude. A dollar value can be placed on the saving of soap or syndets by the use of soft water (see Table 1).

If the water used by a family were softened in a municipal softening plant from a natural water hardness of 380 ppm to a hardness of about 100 ppm a considerable saving would result. Assuming the United States average residential water use is 53 gpcd, based upon the data from the 86 cities discussed, a family of five would use a total of 96,725 gal per year for all purposes around the home. At the indicated average cost of 7 cents per 1,000 gal for softening the added cost for softening these 96,725 gal of water would be $6.77. The annual costs of syndets for cleaning, as shown in Table 1, were:

When using 380-ppm hardness water	$63.90
When using zero hardness water	$30.24
Annual saving	$33.66

If muncipally softened water were

provided, the water would have a hardness of about 100 ppm. The quantity of syndets or soap required when using this water would be closely proportional to the relative hardness of the water. Therefore, the annual cost of syndet cleansing agents under these conditions would be approximately:

When using 380-ppm hardness water	$63.90
When using 100-ppm hardness water	$39.10
Annual saving	$24.80

This indicated saving is at 1955 costs for cleansing agents. At 1958 costs, the saving would increase about 10 per cent to a total of $27.28 per year.

The annual net saving that a family of five could realize from the municipal softening of the domestic water supply from its natural hardness of 380 ppm to a total hardness of about 100 ppm would be:

Saving in cost of syndet cleansing agents by using 100-ppm hardness water rather than 380-ppm hardness water	$27.28
Cost of municipally softening all water used by a family of five	$ 6.77
Net saving in cost of syndet cleansing agents per family of five	$20.51

For the average United States family of 3.5 persons, this net saving, solely in the cost of syndet cleansing agents, would be $14.35 per family per year. The corresponding net saving when using soap as cleansing agents would be about $24.30 per family per year. When a fair dollar value is placed on the other benefits derived from the use of soft water the total net saving would probably be at least twice the savings indicated for the syndets alone. The saving would thus approximate at least $30 per year for the average family of 3.5 persons. When soap is used alone, this would increase to about $40 per family per year. For a city of 35,000 persons, these savings would amount to somewhere between $300,000 and $400,000 per year, depending upon the ratio of use of the syndets to soap.

If residential water consumption were as high as 122 gpcd, the cost of municipal softening per family would increase, but the net savings for syndets alone would still be approximately $8.20 per year for a family of 3.5 persons. The other less tangible savings would be the same as, or greater than, estimated in this discussion, so the total net saving for consumers using 122 gpcd and syndets as cleansing agents would be about $24 per year per average family. The corresponding figure when using soaps as cleansing agents would be about $34 per year per family.

Summary

It is evident from the analysis of the facts that the advent of the synthetic detergents has not changed the economic desirability of water softening. The consumer will save an appreciable amount of money each year if hard water is municipally softened, even though he should decide to soften the water further by rental-type or household cation-exchange softeners. The actual amount of saving realized will depend upon the: [1] average per capita water consumption, [2] hardness of raw water, [3] hardness of the softened water, [4] total cost of softening, [5] relative proportionate use of syndets and soap, [6] cost of syndets and soap, and [7] cost of plumbing facilities and services.

The examples cited indicate an annual net saving of about $24-$40 per average family of 3.5 persons when softening water in a 30-mgd treatment plant from a total hardness of 380 to 100 ppm. The range of saving will depend upon the ratio of syndets to soap used and upon the per capita consumption of domestic water.

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Discussion

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The writer is essentially in agreement with the conclusion that municipal softening plants can provide the best and most economical means of hardness reduction. In any case, esthetic considerations as well as savings, even apart from savings in syndets and soaps, probably far outweigh the costs of hardness reduction.

The data in this field are still, however, insufficient. Certain aspects of the problem, as presented by W. W. Aultman, appear to require further discussion.

Cost of Operation

For some treatment plants the cost of operation is one thing but the charge to the domestic consumer is

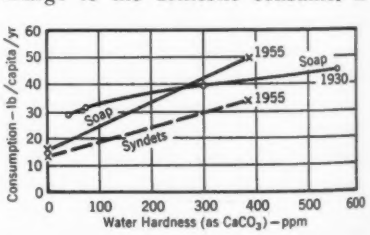

Fig. 2. Soap and Syndet Consumption versus Water Hardness.

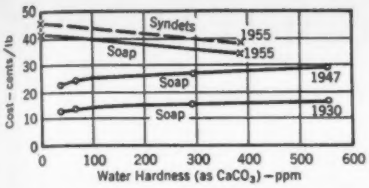

Fig. 3. Soap and Syndet Cost versus Water Hardness.

another. The author knows of one municipal water plant with a 10-15 mgd capacity which specified a softening increment of 21 cents per 1,000 gal for small domestic consumers. For the average domestic consumer the increment was 14 cents per 1,000 gal and for commercial and industrial consumers, 2 cents. It is evident in this case that the domestic consumer, upon whom detergent saving data are based, would be paying much more than the operation cost per 1,000 gal.

Cost and Use Data

The writer has certain reservations about accepting the Purdue University data[1] cited by the author. The "average" individuals and families upon which this study relies would not necessarily be statistically representative of actual individuals or families. By the same reasoning, one 5-member family, the individual members of which are not described, does not necessarily indicate the per capita average for the country. (It may, however, be representative of similar 5-member families.)

The Purdue University study probably is the best that could be made with the funds provided. It should, therefore, be of interest to compare these data with those of a retail sales study made in 1930[2].

Figure 2 shows the consumption of soaps in 1930 and consumption of syndets and soaps in 1955. The low consumption for zero hardness is not surprising. It is reasonable to expect a more rapid increase in consumption in the lower ranges of hardness (zero-40 ppm).

Figure 3 compares the cost of soaps in 1930 and 1947 and syndets and soaps in 1955. An examination of the Purdue University study discloses that the Warren family used the same priced soaps, syndets, and shampoos with soft water as with hard. The bulk of the savings recorded during the soft-water periods occurred with lower-priced syndets and soaps. As a result, the average cost per pound of the *total* annual consumption was greater with soft water than hard. Another relevant factor may be that advertising pressures had greater influence on the consumer in 1955 than in 1930 and would have influenced buying habits even if water hardness were zero.

Figure 4 combines the data of Fig. 2 and 3 on the basis of cost per capita per year. The estimates for the year 1947, which preceded present significant use of syndets, increased use of automatic washers, and other factors, were secured by multiplying the 1930 data by 1.8.

Insufficient Data

A straight line is the shortest distance between two points, but two points of unknown confidence limits do not require a straight-line relationship. The straight line may express the correct relationship, but this would appear to be a coincidence in view of the 1930 data on annual pounds per capita use and costs per pound of detergent. Detergent-use economics may possibly be better represented by a curve similar to the 1955 cost line in Fig. 4. The correct relationship has not yet been conclusively established.

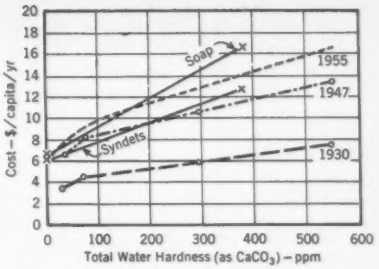

Fig. 4. Cost of Cleansing Agents versus Water Hardness.

The available data on water softening and detergent economy demonstrate that hard water requires the domestic use of more syndets and soaps than does soft water. There is a positive need, however, for better data than are now available.

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2. Hudson, H. W. & Buswell, A. M. Soap Consumption and Water Quality. *Jour. AWWA,* **24**:859 (Jun. 1932).

IRON AND MANGANESE REMOVAL

From Municipal and Industrial Water Supplies

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The common occurrence of iron and manganese in the earth's crust results in these elements being found, to a greater or lesser extent, in many of our natural water supplies. They exist in insoluble forms, in sand and gravel. Under favorable conditions they will be converted to soluble forms and appear in any waters with which they come in contact.[1] Well waters, for example, which are frequently high in carbon dioxide and low in dissolved oxygen, will readily convert insoluble manganese and iron to soluble forms as the waters pass through successive strata of the earth. [2] [3]

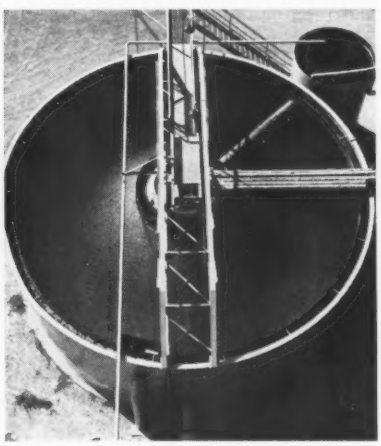
Iron and manganese are normally found in water supplies as: [4]

1. Ferrous and manganous sulfates in those rivers, lakes, and reservoirs containing acid wastes; or in ground waters containing sulphur, particularly as hydrogen sulfide.
2. Ferrous and manganous bicarbonates in those ground waters containing high amounts of free carbon dioxide.
3. A complex combination of iron and organic matter commonly referred to as organically bound iron—in both surface and ground supplies.

Iron in the ferrous state, when brought into contact with the air, combines with oxygen to form ferric oxides which impart a yellow or reddish cast to the water.

Oxides of both iron and manganese will cause unsightly staining of household porcelain and chinaware. They will also stain clothing and textile products and handicap quality control in tanning, dyeing and laundry plants. In boiler feedwater to the presence of iron may be another potential source of scale formation.[5] Manganese in water is similarly undesirable but a plant designed for iron removal without proper attention given to manganese may be inadequate for the removal of both.

Because of the variable nature of the factors involved, no single method of iron and manganese removal can be applied to all situations. Only an individual approach will determine the method to provide the most complete and economical removal. Reliable analyses must be made to determine the amounts of iron and manganese present and the forms in which they occur. It should be determined if softening of the supply is desired along with iron and manganese removal so that softening equipment may be installed simultaneously.



Basically, there are seen methods of iron and manganese removal,[4] each of which can be modified by variations to meet individual requirements.

Open Coke-Tray Aeration Method

This is the most common aeration method used for iron and manganese removal and is indicated in Fig. 1. In it two or more perforated-bottom wooden trays, arranged one over the other, are supported by a wooden or steel framework directly above a 20 to 40-minute wooden or concrete detention basin. When excessive CO_2 is present, an alkali such as soda ash, caustic soda or lime may be added to the aerated water to neutralize the excess and prevent service-line corrosion.

Water entering at the top of the aerator is distributed over the top coke tray. As it percolates downward through the layers of coke, the water comes into prolonged contact with air that is (1) pocketed in the porous structure of the coke, (2) circulating through the voids between the coke, and (3) sweeping through the aerator between the coke trays.

Iron and manganese are converted to their oxidized state,[1] liberated CO_2 and H_2S[6] are swept out of the aerator into the atmosphere, heavier oxides settle in the detention basin and the lighter ones are carried to the filter where they are trapped and removed by backwashing. This method is generally employed wherever moderate amounts of easily-oxidizable iron are present.

Open Slat-Tray Aeration Method

In this method as shown in Fig. 2 the coke trays are replaced by wooden slat trays. The unit is composed of a large number of horizontal cypress or redwood slats arranged in staggered tiers. The framework upon which the slats rest is usually enclosed on all sides with wooden louvers. Below the aerator is a concrete detention basin for settling of the heavier particles of oxidized iron and manganese.

Water entering the aerator above the top layer cascades[6] downward from tier to tier coming into frequent contact with circulating air. Iron and manganese are oxidized and

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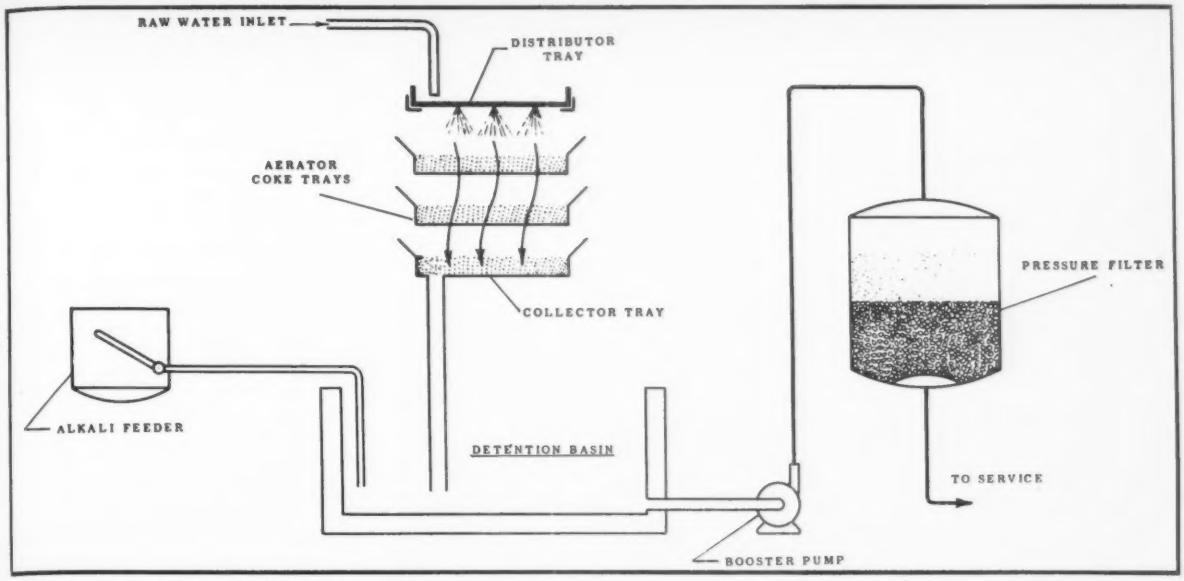


Fig. 1. Open Coke-Tray Method of Aeration.

any liberated carbon dioxide and hydrogen sulfide gases are carried away by the air.

A pump taking suction near the bottom of the detention basin boosts the water to standard pressure or gravity filters where remaining traces of iron and manganese are removed. As in the first method an alkali feeder is provided to neutralize any excessive CO_2 remaining in the water.

Slat-tray aerators are often preferred to coke-tray aerators because the slats are easily removed for cleaning or washed in place and because periodic replacement of coke beds is eliminated. Coke trays, however, usually provide more complete aeration.

Closed Forced Draft Aeration Method

As shown in Fig. 3 the forced draft aerator consists of a large number of wooden slat trays enclosed in a cylindrical or rectangular shell. As water cascades downward through the staggered tiers, a motor-driven blower forces pressurized air upward between the slats counter-current to the flow of water.[6] Iron and manganese are thus oxidized and carbon dioxide and hydrogen sulfide gases liberated.

The forced draft aerator is more expensive than the first two but it has these advantages: it can be operated successfully at a higher flow rate of 10-25 gpm/sq. ft. permitting use of a smaller tank; the volume of air delivered to the aerator can be correctly proportioned to the amount of iron in the water; the unit can be located either indoors or outdoors; the sides can be designed as hinged doors for easy cleaning.

As in other aeration methods, a detention basin is located beneath the aerator and a booster pump transports water from the basin to standard pressure or gravity filters for final removal of iron and manganese oxides.

Iron and Magnanese Removal by the Solids-Contact Process

Where hardness and turbidity removal is required in addition to iron removal, a solids-contact unit such as the Graver Reactivator may be effectively employed. Complete treatment

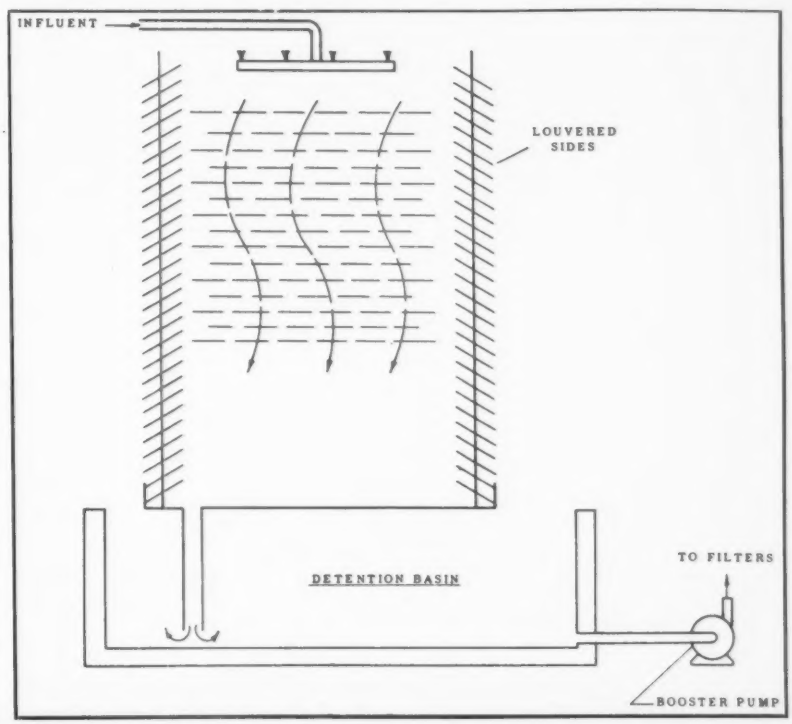
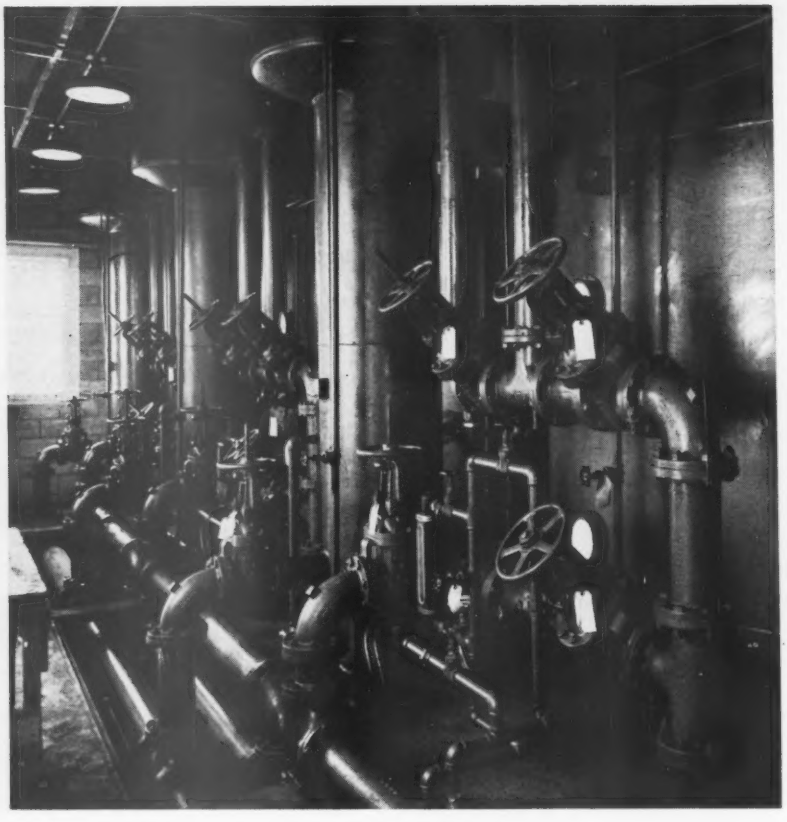


Fig. 2. Open Slat-Tray Aerator.



can be accomplished in one unit. Depending on the nature and amount of iron found in the water, three arrangements are possible each calling for standard pressure gravity filters to follow the solids-contact unit.

The first arrangement provides for the removal of iron and manganese mainly by catalytic action and coagulation. It is known that the higher oxides of iron and manganese have a catalytic effect on iron and manganese in solution. A filter bed coated with these higher oxides is said to be "seasoned." The same principle applies to the sludge bed in the Reactivator. Here these higher oxides act as a catalyst between the iron and manganese and the dissolved oxygen in the water. The resulting precipitation, assisted by a coagulant aid and an alkali for pH adjustment, produces a clarified water substantially free from iron and manganese.

In the second arrangement an air grid sludge recirculator is substituted for the standard mechanical impeller recirculator. This introduces oxygen to the water and oxidizes the iron more completely.

The third arrangement as shown in Fig. 4 provides for an open aerator mounted on the Reactivator. This is particularly effective when, in addition to high iron and manganese content, the raw water contains an excess of carbon dioxide and hydrogen sulfide gases.

Air, sweeping through the aerator, provides enough oxygen to hydrolyze the ferrous and manganous compounds and simultaneously carry off liberated gases.

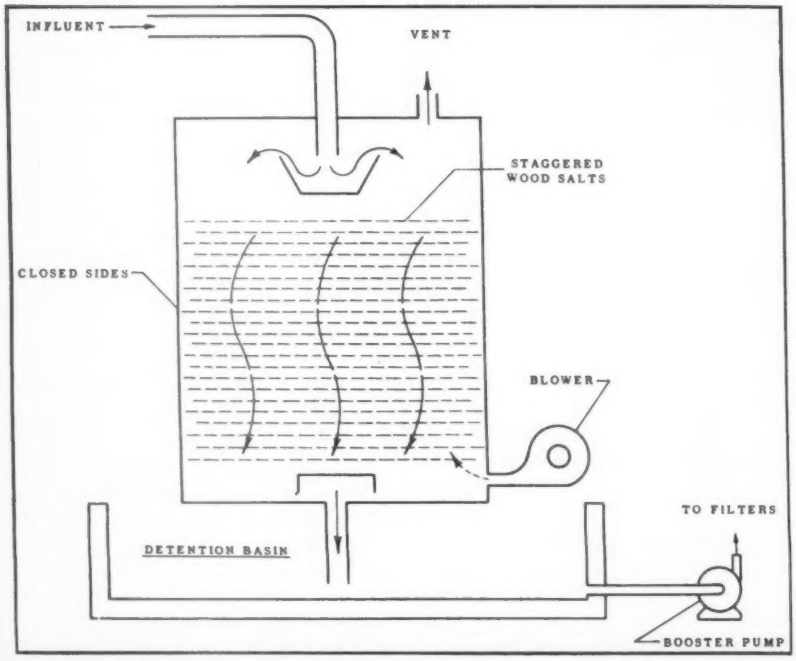


Fig. 3. Closed Forced Draft Aerator.

Iron and Manganese Removal by the Pressure Diffuser Method

The economy and compact size of the pressure diffuser method indicated in Fig. 5 make it ideal for both large and small plant operation. It is composed of a vertical, cylindrical pressure chamber or diffuser into which compressed air is injected through a specially-designed perforated distributing device near the tank bottom. Raw water, flowing through the tank, becomes saturated with sufficient oxygen to oxidize any iron and manganese present in the water before it reaches the filter bed.

A solenoid valve, located in the air line between the compressor and the diffuser tank and energized from the pressure switch controlling the operation of the well pumps, automatically stops and starts the flow of water through the diffuser tank. A pressure relief valve, located in the air line between the solenoid valve and the diffuser tank eliminates excessive pressure on the filters in case the solenoid fails to operate. A needle valve in the air line ahead of the solenoid valve permits manual propor-

tioning of the amount of air in relation to the amount of iron contained in the water.

Free air entrapped in the water entering the filters is released when the water strikes the distributor baffle in the top head of the filter tank. The air then escapes through an automatic air relief valve adjacent to the baffle.

Sodium Zeolite Softening and Iron Removal

When water softening is combined with iron and manganese removal, an arrangement as shown in Fig. 6 is often used. The main flow of water is pumped directly to the sodium zeolite softeners where iron is removed and hardness reduced to zero by the base exchange method. Since the desired standard for hardness in municipal water supplies is 3 to 5 grains per U.S. gallon, by-passed raw water, which has been treated for iron removal by aeration and filtration, is added by means of a by-pass proportioning valve to produce the correct hardness.

When operating zeolite softeners for the removal of iron and manganese, it is important to avoid contact between the water and air before reaching the zeolite softener since oxidation of these impurities will cause zeolite grains to become coated with precipitates which will eventually shorten their capacity and create channelling through the zeolite bed.[3]

Iron Removal by the Manganese Zeolite Process

This method shown in Fig. 7 is similar to the sodium zeolite softening method except that a manganese zeolite iron remover is used in place of the aerator and filter.

Manganese zeolite is siliceous-type greens and zeolite which has been treated with manganous chloride to convert it by base exchange to manganese zeolite. A potassium permanganate solution is used to regenerate the zeolite. In this process, the regenerant combines with the zeolite to form an oxide coating on the surface of each grain of zeolite. The purpose of this oxide coating is to serve as a store of oxygen. As iron and manganese in solution enter the zeolite bed, they combine with oxygen which is released from the oxides formed during regeneration to form new oxides. When the store of oxygen is nearly depleted, the zeolite bed is again reoxidized by regenerating it with a permanganate solution.

The iron precipitates lodge in the bed of zeolite and require daily backwashing for removal. Since the proportion of by-pass water to softened water is usually small, the cost of removing iron by this method is in line with other methods, particularly for small plant operation. However, in large plants, the cost of potassium permanganate may be an objectionable feature of this method. This method is generally used wherever very low amounts of iron and manganese are present in the raw water and wherever very small amounts of iron and manganese are required in

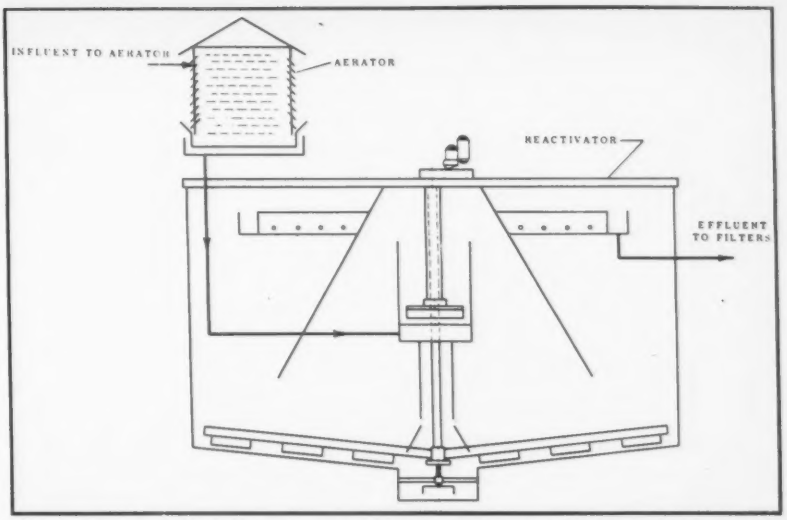


Fig. 4. Graver Reactivator Used For Precipitation and Solids-Contact Process of Iron Removal.

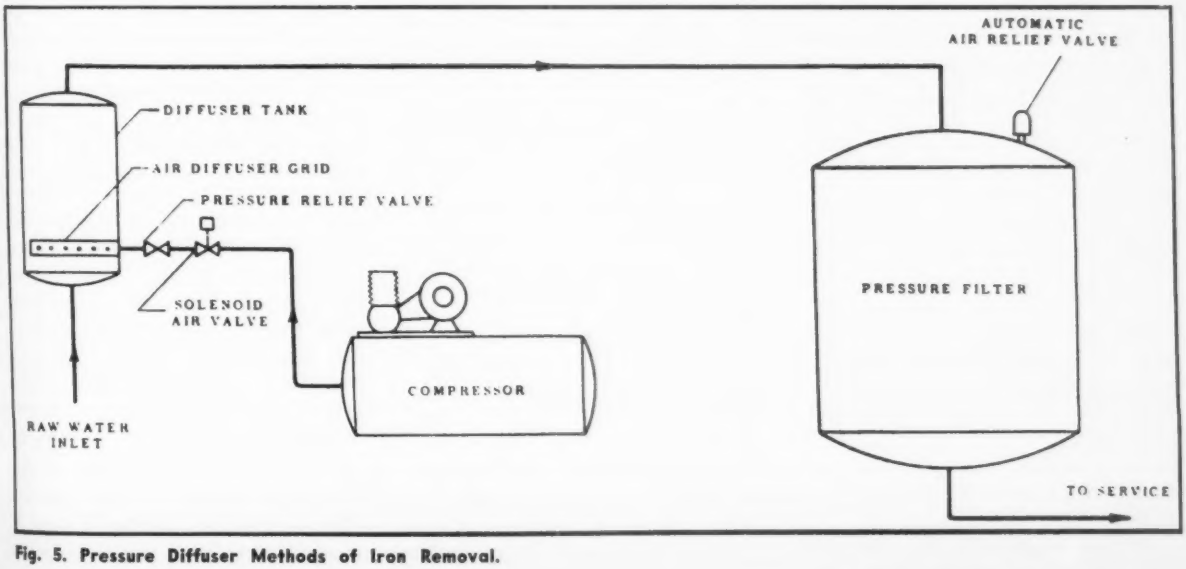


Fig. 5. Pressure Diffuser Methods of Iron Removal.

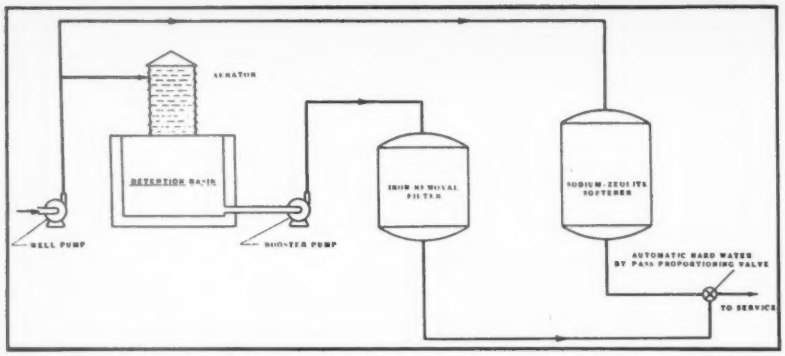


Fig. 6. Sodium Zeolite Softening Combined With Iron Removal.

the final treated water.

When water supplies contain excessive amounts of iron or manganese, operational costs can be reduced sometimes by passing all of the water through an aeration and filtration system before softening and blending. On rare occasions, a manganese zeolite iron remover is installed in the by-pass line to further reduce the iron and manganese in the blended water. However, this polishing operation is not usually necessary in municipal applications.

The seven systems discussed here incorporate most of the common methods of iron and manganese removal. Obviously, the choice of a method or combination of methods depends on many considerations. Because of the variety of possible combinations, only proper evaluation of all the factors involved will indicate which one will produce and insure the desired results of iron and manganese removal.

Experience has shown that in most cases the installation and operation of a pilot plant under carefully supervised conditions can help to pin-point the most economical method of treatment. Following are five case histories of iron and manganese removal problems in various municipalities and industrial plants which should provide some evidence of this.

Case 1—Northeastern City

A northeastern city wished to set up a municipal water treatment plant with a future capacity of 2,000,000 gpd. The results of many analyses taken indicated average total iron of about 14 mg/l and total manganese of about 27 mg/l. Low organic content in the water made it probable for iron precipitation by pressure and open aeration and filtration.

It was decided by the city and consulting engineers to first set up a pilot plant at this city.

Pilot Plant

As shown in Fig. 8 this pilot plant consisted of two tanks, 3 in. diameter x 5'4" high, fabricated of Lucite and auxiliary equipment, consisting of aeration tank, piping, valves, fitting, flow meter, internal piping, graded sand and gravel or anthracite and manganese zeolite. This unit was preassembled and mounted on a wooden frame with convenient access to valves and operating units. Connections were provided for raw water inlet, treated water outlet, waste connections, and chemical feed inlet to the manganese zeolite cell. Fully loaded, the pilot plant weighed approximately 100 lbs and was easily moved from one location to another since the frame was mounted on casters. Operating rates based on normal filtration rates of 2 to 3 gpm/sq ft were 0.098 to 0.147 gpm as the total-filter area was 0.049 sq ft. A pressure regulating valve was provided at the inlet to the pilot plant and set so that the maximum pressure the pilot plant was subjected to was 15 psi. If an air compressor were available, it would be connected to the discharge side of the pump in order to provide air for pressure areation and oxidation of the iron and manganese in the water. In the case of this pilot plant, a compressor was not available so that air was furnished by means of a snifter valve located on the suction side of the pump.

Operation of Pilot Plant

A pressure aeration iron removal system is basically a filtration oxidation plant with auxiliary equipment provided to furnish the means to affect the treatment results desired. After an initial operating and seasoning period, the granules of sand, quartz or non-siliceous material accumulate coatings of catalytic iron and manganese oxides that promote further rapid oxidation. It is therefore important to operate the pilot unit until proper seasoning of granules occurs.

The filtration of water is a process for the removal of all suspended matter visible to the eye, including the finest particles of organic matter which exist in the state of suspension. At the same time, colored matter is partially removed. The common method of filtration is simply a matter of passing water downward by pressure or gravity through layers of finely graded sand, quartz, or a non-siliceous material. The operating period of the filter depends upon the volume of water passing through the unit and the amount of suspended matter of turbidity removed. After a certain period, the filter bed becomes coated and offers excessive resistance to flow. This occurs when the pressure loss across the filter is from 3 to 5 lbs per sq inch. A pressure loss across the unit of this magnitude indicates that the filter should be backwashed by reversing the flow of water through the unit until the backwash water to waste is again clear. In most cases, this period of backwashing is from 10 to 15 minutes. By reversing the flow of water through the unit, the filter bed is raised, loosened and regraded. Suspended matter collected during the operating period is washed out to waste with the backwash water. Backwash rates are largely determined by the size of the filter and are usually modified by the backwash results obtained in practice. In pressure filters utilizing anthracite as the filter media, the backwash rates range from 8 to 10 gpm per sq ft of filter area. Where sand and gravel is used as the filter media in pressure filters, the backwash rate is usually 10 to 12 gpm/sq ft of filter area. For gravity filters of either type of filter media, the backwash rates are usually higher. For anthrafilt the backwash rates range from 12 to 15 gpm/sq ft of filter area, and for sand and gravel, from 15 to 20 gpm/sq ft of filter area. In any case, excessive backwashing is to be avoided in order to preclude the possibility of washing the filter media out of the unit. On the other hand, if the backwash rate is too low, the bed will not be properly

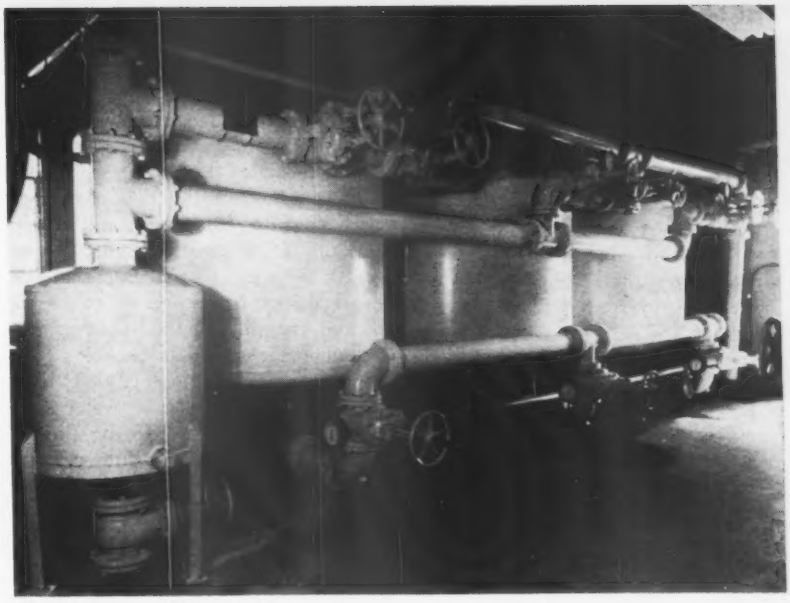
cleaned or graded. After backwashing has been completed, a short rinse period is recommended for the purpose of resettling the bed before placing the filter back into service.

In a pressure aeration iron and manganese removal system, aeration is used in combination with filtration to remove soluble iron by contact catalysis and oxidation and subsequent precipitation and filtration. Air and raw water are mixed ahead of the filtration unit for a period of time, usually 1 minute, in a separate mixing chamber containing graded gravel or raschig rings. Graded gravel or raschig rings are employed to provide for a scrubbing action to insure the intimate mixing of air and raw water for the proper oxidation of the iron and manganese in the water. An air relief valve is provided in the top of the filter unit to vent excess air. The ratio of air to raw water can be varied to suit the operating conditions found most satisfactory. Operation of the filter unit is the same as previously described with or without pressure aeration. In addition to aeration and filtration, the pilot plant is provided with an additional unit for further iron removal by passage of the water through a bed of manganese zeolite. The water previously treated by either aeration and filtration or filtration only, enters the top of the manganese zeolite filter and passes down through the bed of manganese zeolite. Here iron is oxidized and precipitated out. When the capacity of the bed is exhausted, the unit is shut down, backwashed, regenerated, and returned to service. Regeneration is accomplished with a weak solution of potassium permanganate which is siphoned in. In addition to the above equipment, a small positive displacement diaphragm pump is furnished with a small crock for liquid chlorine which is pumped into the system between the pressure aerator and the filter.

The pilot plant used in treating the well water at this city included a unit for manganese zeolite. However, it was quickly determined that treatment with manganese zeolite was not required to produce the desired results and in addition it was decided that manganese zeolite would not be practicable for an iron and manganese removal plant of the magnitude proposed, namely 2 mgd. Consequently, the pilot plant was operated with pressure aeration and filtration through the sand and gravel filter supplemented by chlorination applied between the aerator and the filter.

Table 1
Iron & Manganese Analyses Northeastern City

Water	Fe Mg/l	Mn Mg/l
Raw	15.8	0.4
Treated	0.1	0.1
Raw	9.0	not tested



TYPICAL installation

The Pilot Plant Approach

Considering the many ways in which iron and manganese concentrations can be reduced, the varying character of natural waters, and the various states in which iron and manganese can be present, there should be no question that the soundest approach to the problem is testing in a pilot plant operation. Although the selection of a satisfactory method or process is often made on the basis of experience and judgment, a pilot plant provides the refinement of choice required by smaller communities where the most important criteria is economics.

The pilot plant provides pressure aeration, upflow contact within the aerator, downflow filtration through sand and gravel or anthracite, downflow through manganese Zeolite and chemical feed facilities for alkali and chlorine. The flexibility of the pilot plant permits operation of any one or any combination of these facilities.

The pilot plant approach affords the soundest basis for solution of iron and manganese problems. It is particularly useful for smaller communities, where available funds for treatment facilities are usually limited. In addition, the variety of methods which can be employed confronts the engineer with the problem of weighing one method against another. The process of elimination often figures prominently in the ultimate selection of a satisfactory method. Therefore, there is no better starting point than the pressure aeration-filtration pilot plant because, if satisfactory:—

1. It is particularly suitable for the flow requirements of small communities.
2. It is extremely flexible and can be used for a variety of chemical feeds including alkali, chlorine or chlorine dioxide.
3. It is flexible in application and can be used readily in conjunction with manganese Zeolite or sodium Zeolite softening.
4. It requires mimimum skilled attention and is well suited to automatic operation.
5. It is most economical to install and operate when compared to the other methods.

Test Methods

The test method used for determination of iron was the field method based on the development of the red color of ferric thiocyanate produced by the reaction of potassium thiocyanate solution with ferric iron present in the water sample. The color developed matched with color standards and the iron content in ppm read directly from the slide of the Taylor Water Analyzer. No field test was made for the determination of manganese. However, samples of the raw water and treated water were analyzed in the laboratory and the results obtained were tabulated on the attached table of treatment results showing the raw water iron and manganese and the effluent water iron and manganese with the type of treatment used. The laboratory method for determining the iron in the water is an extension of the rapid field method previously described which involves the boiling down of the sample with dilute hydrochloric acid to place all of the iron in solution before following the standard procedure for the rapid field method. The test for manganese is based on the oxidation of the manganese ion to permanganate in the presence of nitric acid and ammonium persulphate. The color developed is matched with color standards and the manganese content in ppm is read directly from the slide of the Taylor Water Analyzer.

Conclusions

Although a pilot plant operation was conducted over a relatively short period of time, and operating conditions were far from optimum due to difficulties in maintaining relatively constant flow rates with proper aeration due to snifter valve arrangement aerating the raw water, it nevertheless was determined that pressure aeration followed by filtration, supplemented with chlorine feed could and would produce an effluent containing iron and manganese to the extent of 0.2 mg/l or less. Inspection of table 1 indicates that this method of iron and manganese removal is feasible. This iron removal plant employs essentially pressure aeration to treat water containing 15.8 mg/l and 0.4 mg/l manganese, operating at a flow rate of 3 gpm/ sq ft. Graded anthracite was used as a filter media to produce consistently an effluent containing 0.2 mg/l combined iron and manganese with service runs approximately 24 hours with an appreciable saving in backwash water due to using anthracite.

It was reasonably expected that the raw water iron would remain at 15.8 mg/l or possibly drop to values lower than that. Such a system would not only provide an effluent of desired quality but in addition is much more economical from a capital cost viewpoint than any other type of iron removal system because of the relative simplicity of the equipment required. On the other hand, if the raw water iron had been expected to increase over a period of time, an open aeration system followed by sedimentation and filtration by means of either gravity filters or pressure filters utilizing graded anthracite filter media would have been more feasible. Such plants involve a larger capital expenditure, where gravity filters are employed in that a clearwell would be required as well as backwash pumps to backwash the filters. Where pressure filters are used a clearwell and backwash pump would not be required because the pressure filters could be backwashed with the effluent from the filters remaining in service.

Table 2
Iron Removal At Eastern Steel Plant

		Mg/l As Filtered Sample
Total Hardness	$CaCO_3$	128
M. O. L.	"	156
Phen. Alk.	"	-
CO_2, Free	CO_2	14
pH		7.1
Iron, Total	Fe	0.2
Manganese	Mn	1.0
Silica	SiO_2	<1
Turbidity (after shaking)		<5
Color		20
Odor		None

Results from pilot plant testing are shown in Fig. 9. Fig. 10 shows a sketch of the plant recommended for this city, including compressor, pressure aerator, chlorinator, and six 120" x 5' straight height vertical pressure filters.

Case II—Eastern Steel Mill

A large eastern steel plant had a chronic problem of iron removal. There were three wells at the subject plant. The 2 wells under consideration were B Well and C Well. Capacities of these wells were about 4000 gpm. C Well was the highest in iron content running from about 13 to 16 mg/l almost continuously. B Well ran about 1 to 1½ mg/l of iron when operating just from the well head, i.e., with all the laterals of the well closed. With the laterals open, the iron would go up to 8 mg/l or higher. The people who put in the wells had been trying to eliminate the iron problem from these wells unsuccessfully for 2 or 2½ years. The well people had tried a combination aerator and filter. However, discussion with plant personnel disclosed that the filter media was Anthrafilt and that the areator was a simple hand-aspirating bulb. One of the problems mentioned in the test run by the well people was short runs caused by the top of the bed cracking and causing channelling with the result that the iron content was quite high.

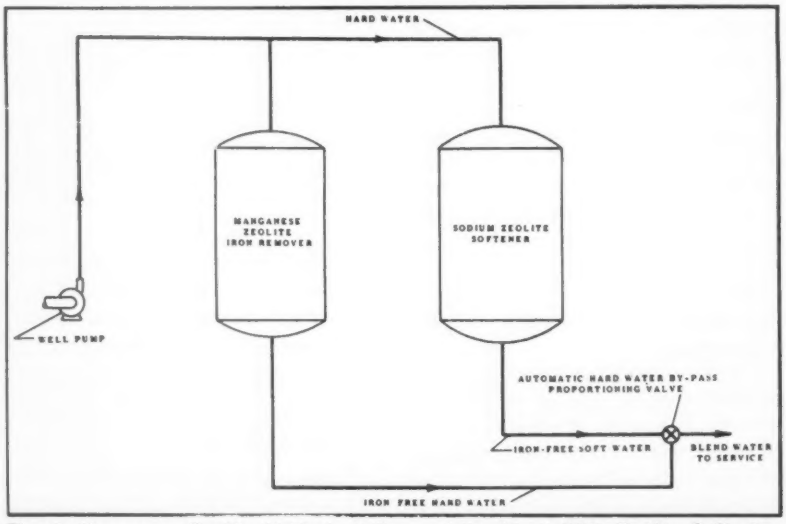


Fig. 7. Manganese Zeolite Method of Removal Combined With Zeolite Softening.

Table 3
Iron & Manganese Removal Plant
Eastern Steel Plant

Well	Lime Cl_2	Raw Fe	Raw Mn	Raw CO_2	Raw pH	Filtered Fe	Filtered Mn	Filtered CO_2	Filtered pH
A		5.8	1.6	42	6.4	1.95	1.55	10	7.1
A		5.6	1.7	44	6.7	0.08	1.5	7	7.4
B		0.45	0.47	49	6.5	.005	0.27	5	7.4
A	1.5 Cl_2								
	0					0.1			7.3

A pilot plant was accordingly set up and produced the results shown in Table 2 by pressure areation and addition of lime and chlorine in small amounts. Total iron was reduced to 0.2 mg/l and manganese to 0.2 mg/l Later tests, as shown in Table 3 showed iron reduced to 0.1 mg/l and manganese to 0.4 mg/l. A large iron removal plant is being engineered based on these data.

Case III—Eastern Municipality

Another pilot plant similar to the one described above was set up at an eastern city. Here, as shown in Table 4, iron ran as high as 12.0 mg/l and manganese at 0.2 mg/l. Results from the pilot plant tests showed a reduction of iron and manganese to 0.1 ppm each. Table 5 and 6 shows a later series of tests made with the pilot plant. Recommendations were made for an iron removal plant similar to the one shown in Fig. 9.

Table 4
Iron & Manganese Removal Plant
Eastern City

Mg/l Fe	Mg/l Mn	Flow Ml/Min.	Flow Rate GPM/Sq Ft
12.0	0.2	Raw Water	
0.15	<0.1	400	2.2
0.2	<0.1	450	2.5
0.1	<0.1	500	2.7

Case IV—Midwestern Paper Company

At a large midwestern paper company, another chronic iron removal problem existed. This company previously had installed three horizontal pressure manganese zeolite units, 8′ in diameter x 25″ long. This plant was intended to remove iron and manganese from some deep wells. These wells contained about 1 to 2 mg/l of iron as F e and about 0.3 to 0.5 mg/l of manganese as Mn. Each of these filters was guaranteed to deliver 3,000,000 gallons of water between regenerations with permanganate delivering a water having an iron plus manganese content of under 0.2 mg/l.

This plant had never given proper results. The capacity between regenerations was as low as 600,000 gallons instead of 3,000,000 and the iron and manganese broke through into the effluent erratically. During some runs, the iron would be low throughout the run but the manganese would break through much sooner than expected. It was found that the manganese zeolite bed and even the gravel below the zeolite had become coated with iron.

Table 5
Eastern City Iron Removal Plant

	Mg/l As	Raw Water Before Treatment	Treated Water
Total Hardness	$CaCO_3$	120	122
M. O. L.	"	101	103
Phen. Alk.	"	0	0
CO_2, Free	CO_2	7	7
pH		7.1	7.1
Iron, Total	Fe	7.3	<0.1
Silica	SiO_2	1.5	1.5
Turbidity		100	5
Sediment, Color		Brownish	Brownish
Sediment, Nature		Iron Dustlike Particles	
Color		10	<5

As a result of improper performance of the plant, the rags which were boiled in kiers with alkali and chemicals in the water taken from these filters became brown due to the manganese. This interfered with the paper-making process and caused excessive losses in rag tonnage running into many thousands of dollars.

It was concluded that the trouble was due to the fact that the ratio of iron to manganese in the raw water was so high that the iron coated the manganese zeolite and prevented the manganic oxides on the zeolites from properly removing the manganese. It was suggested that the solution would be to precede these manganese zeolite units by Anthrafilt filters and that air should be introduced just ahead of these filters to oxidize the iron under pressure.

In order to prove that this recommendation was the proper solution, two pilot filters, 6″ diameter with 27″ beds of Anthrafilt and manganese zeolite were installed in series. Into the Anthrafilt unit, which was the first unit, compressed air was introduced. The results of this pilot test confirmed views that the Anthrafilt filter would remove most of the iron, leaving the manganese removal to the manganese zeolite unit. This company obtained full capacity from the manganese zeolite unit between regenerations, with iron plus manganese under 0.2 mg/l in the effluent.

As a result of this successful field work, the plant shown in Fig. 10 was installed. This plant includes rotary surface washers in the two Anthrafilt filters as well as in the three existing manganese zeolite units. It also includes the air saturator tank into

Table 6
Iron Removal By Pressure Aeration And Filtration
Eastern City

Time	Flow GPM/Sq Ft	Psi Inlet	Psi Outlet	Fe Mg/l Raw	Fe Mg/l Filtered	CO_2 Mg/l Raw	CO_2 Mg/l Filtered
4:00	3	41	42	>0.1		5.3	
4:30	3.3			5.5	0.1	6.2	
4:00	2.85	44	46		0.1	7.1	4.4
10:00	2.7	45	47		0.2		5.3
3.30	2.85	43	44		0.15		5.3
2.20	3	45	47				
10:50	3	43	45		0.1		
10:45	2.85	39	41		0.1		5.3

Table 7
Iron Removal Plant Eastern Power Company

	Mg/l As	No. 2 Well	No. 3 Well	No. 4 Well
Total Hardness	$CaCO_3$	36	24	26
M. O. L.	"	1	9	0
Phen. Alk.	"	0	0	0
CO_2, Free	CO_2	3	3	4
pH		4.5	6.3	4.15
Iron, Total	Fe	23.7	47.0	12.6
Silica	SiO_2	9	7	10
Turbidity (After shaking)		40	>100	>100
Sediment, Color		Brownish	Brownish	Brownish
Sediment, Nature		Fine	Large Iron Particles	Fine
Colored, Filtered		<5	<5	<5
Odor		None	None	None

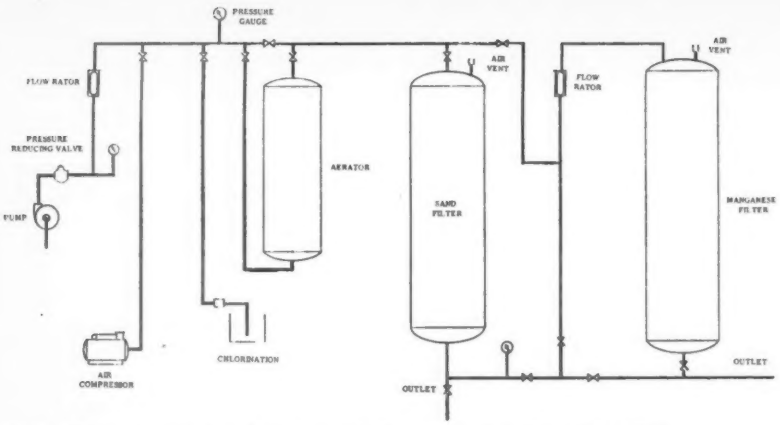


Fig. 8. Flow Diagram for Iron Removal Pilot Plant for Field Operation.

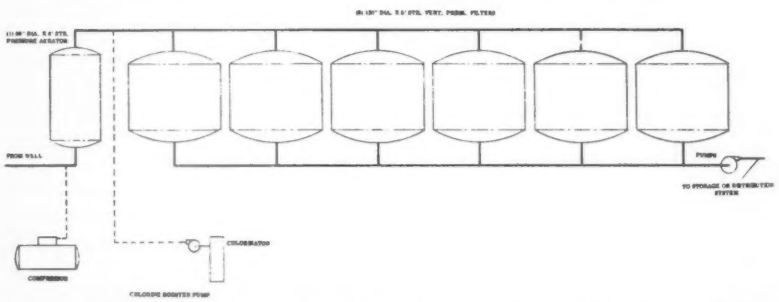


Fig. 9. Pressure Aeration Iron Removal Plant Recommended For A Northeastern City.

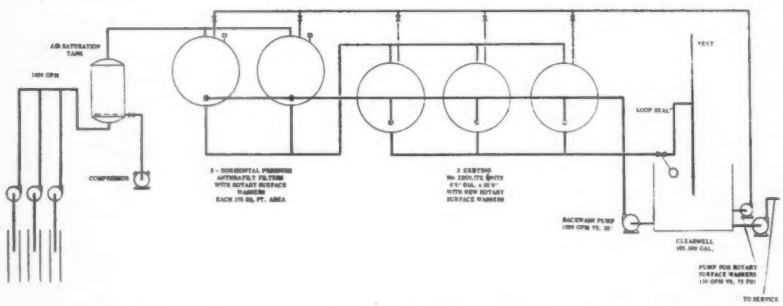


Fig. 10. Flow Diagram of Iron and Manganese Removal Plant Installed At A Midwestern Paper Company.

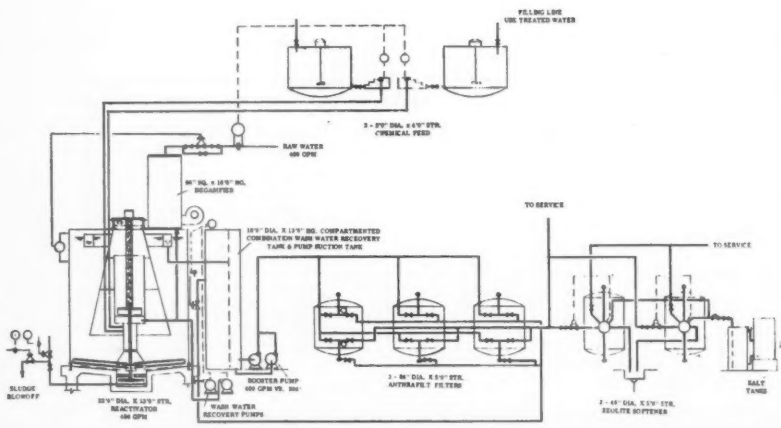


Fig. 11. Flow Diagram of Water Treatment Equipment At An Eastern Power and Light Company.

which the air is introduced. The valves on the front of the two filters were hydraulic gate valves operated by semi-automatic pilot valves. Backwashing and return to service will be automatic after pressing the starting push-button.

Case V—Central Station Power Plant in Northeast

Water delivered from a series of wells at a northeastern power company showed extremely high total iron. Table 7 indicates the analyses of three wells showing total iron ranging from 12.6 to as high as 47.0 ppm. After a complete investigation was conducted the plant shown in Fig. 11 was recommended and installed. Basic components were a 22′ x 18′ straight Reactivator of 450 gpm, chemical feeders, degasifier mounted atop the Reactivator and providing gravity flow to the Reactivator, and three 88″ x 5′ straight height Anthrafilt filters. A combination pump suction tank and wash water recovery tank followed the Reactivator. A recent analysis taken after the plant had been installed showed total iron reduced to 0.3 ppm, free CO_2 to 0.0 ppm, turbidity to 10 ppm, and silica to 3 ppm.

Summary

Experience with these various plants has indicated that very often the use of pilot plants before actual recommendation and installation of specific iron and manganese removal systems can be of great value in determining which type of system will be most effective under existing conditions.

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3. Applebaum, S. B., Iron And Manganese Removal, 16th Annual Water Conference of Engineers' Society of Western Pennsylvania, Oct. 18, 1955
4. Fosnot, H. R., Seven Methods of Iron Removal, *Public Works*, Nov., 1955
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Operating Characteristics of Rapid Sand Filters*

by HERBERT E. HUDSON JR.

Partner, Hazen & Sawyer, Detroit, Mich.

The operating characteristics of rapid sand filters are dependent upon the work they are intended to do, their design, and how they are managed; what is expected of the filters depends on the standards of quality for the product served to the consumer. Three decades ago the water industry was content if treated water had a turbidity of less than 1 ppm, and presence of gas formers in coliform-bacteria tests was tolerated provided the confirmed test was not often positive. Today filtered water with turbidities less than 0.2 ppm can readily be produced at all times, with an average of 0.05 ppm. Many plant operators are nowadays disturbed by a single presumptive test for coliform organisms and deeply concerned when a single confirmed test proves positive. The efficiency of rapid sand filtration must be given more attention if these modern standards are to be met.

Filter Bed Troubles

Although it was once believed that a filter had to be somewhat dirty in order to operate efficiently, it is now known that clean filters do a better job of treatment and that they remain in safe operating conditions at times when dirty ones would fail[1]. The condition of the filter bed is therefore an important consideration for the designer and the operator.

Filter bed troubles may be divided into two kinds: those that start at the top of the filter bed, and those that start at the bottom. Troubles that start at the top of the bed begin with compacted flocculated material, which combines with filter media to produce mudballs. The mudballs grow until they sink during the washing process and come to rest on the gravel bed. There they consolidate into clogged masses, which grow laterally and vertically until they often reach through the entire filter bed. These clogged masses cause maldistribution of backwash and displacement of gravel. Sometimes this displacement is almost volcanic, forcing the gravel upward completely through the filter bed and rendering it ineffective.

The accumulation of flocculated material within the filter bed also changes the filter media from incompressible to compressible and causes compaction during a filter run. This compacting is indicated both by sinking of the sand surface during the filter run and lateral shrinkage, which may open cracks in the bed and along the sidewalls. Through these cracks, water may penetrate to the underdrainage system, thus rendering the filter useless.

On the other hand, troubles may start at the bottom of the filter because of uneven wash water distribution. The maldistribution may be caused by faulty underdrains or by the gravel layers. There is a tendency for gravel to wander, even in the best filters, and thereby reduce maldistribution of the backwash[2]. This is not usually serious enough to impair the overall operation of the filter, but the effects may be cumulative and may ultimately result in projection of the gravel through the sand bed, thus causing failure of the filter. Gravel displacement also leads to leakage of sand into the underdrains and clear wells.

Washing Methods

The obvious remedy for filter troubles is to dismantle the filter, clean its components, and reassemble it properly. When done frequently enough, this can keep a filter in reasonably good condition. In some plants such rehabilitation is done as often as twice a year, which would usually be excessive; but in these plants it was necessary. In others, rebuilding may be necessary only once in 5-30 years.

Some plants have been able to eliminate mud ball troubles by more frequent washings. In one plant in which filter runs of 48 hr or more could be maintained, the operator washes the filters every 30 hr, in spite of the consequent head loss. This is good practice. Another effective measure is scouring the sand surface with a high-pressure stream once a month.

For troubles that begin at the top of the filter, preventive measures may often be taken. The high rate of backwash (20 gpm/sq ft, or more), formerly praised as a preventive measure, has not proved uniformly successful. The use of air wash, widely advocated in the past, has been increasingly abandoned in the United States, though they are still used successfully abroad. These methods probably fail because of a lack of vigor in the application of scouring force.

The most successful filter-washing method used in conjunction with backwashing is the surface wash. The Baylis fixed-jet stream has about one ⅛-in. jet for each square foot of filter area. This system requires about 2 gpm/sq ft at approximately 50 psi. With its fairly extensive pipe network above the sand bed, it effectively cleans the sand.

The filter sweep system devised by Palmer uses fewer jets and requires about 0.5 gpm/sq ft under 50-psi pressure. This system uses jets in rotating pipe arms that swivel horizontally above the expanded bed and in the top of the expanded sand during backwashing. Although this system does not clean the corners as well as the fixed-jet system, it does a satisfactory job.

Both kinds of surface wash are sub-

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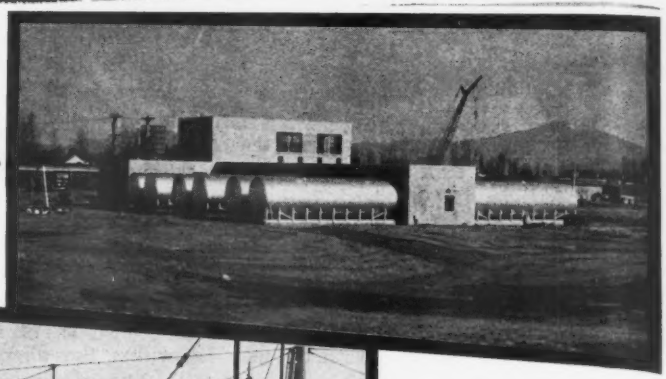

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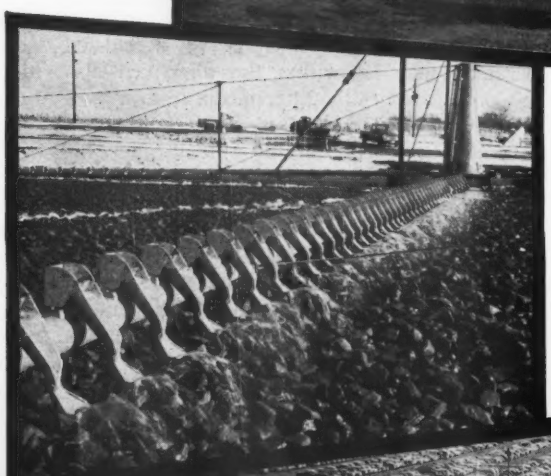

CONTRAFLO type "CW" thickeners and clarifiers for neutralizing of plating wastes.

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ject to enlargement of the jet openings through the combined forces of scouring by sand and corrosion. Steel is therefore unsuitable for the jet; brass is better, but it also wears away. Plastic is reported to give good service.

Without the use of surface wash, mud balls may accumulate and form as much as 10 per cent of the volume of the top 6 in. of the bed in only a few months. Proper washing can prevent the formation of mudballs and thus eliminate all of the filter bed troubles that begin at the top of the bed[1].

Thus far this discussion has been intended to apply to all kinds of pretreatment plants, but softening plants present a further difficulty. In such plants there is the problem of cementation of sand and gravel by chemical precipitates. Owing to the deep penetration of these materials, surface washing is less effective and backwashing is more important. Stabilization of the water before filtration by solids-contact reaction or by polyphosphate treatment also helps.

Underdrain Design

Troubles that start at the bottom of the filter, owing mainly to the maldistribution of backwash water, spring first from the design of underdrains. Underdrain types are given a thorough review by Hazen[3].

Figure 1 represents a hydraulic analysis of an underdrain system. It reveals that one generally ignored hydraulic characteristic of manifold systems is a vital consideration in the design of underdrains. The old practice of relating orifice openings to the area of the bed and similar methods do not produce adequate designs. In addition to the change in pressure along the lateral, a major design criterion is the variation in orifice coefficients along the manifold. Through methods set forth by McNown[4], Fig. 1 was prepared for a perforated-pipe system in a filter 19 ft x 56 ft with underdrain laterals 9.5 ft long. The value Q_l/Q is the ratio of discharge through the orifice to the flow past the orifice in the lateral. This was plotted against a head-loss term (4), $\frac{h_f'}{V_l^2/2g}$, in which h_f' is the head loss through the lateral owing to friction, V_l is the average velocity through the lateral, and g is the acceleration due to gravity. The dashed portion of the curve represents the increased variation that would be expected if longer laterals were used.

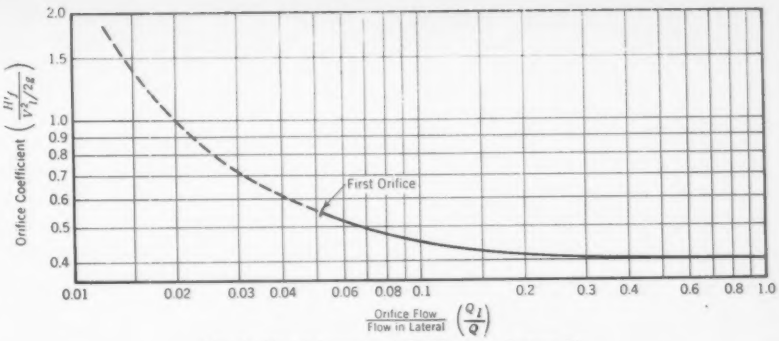

Fig. 1. Head Losses at Orifices in Lateral*

*The laterals of the filter from which data for this curve were taken were 9.5 ft long. The dashed portion of the curve represents losses that could be expected if the laterals were longer.

It can be seen from the figure that there is a tendency for the discharge through the orifices to be lower near the inlet to the lateral than near its terminus. This is because the water has a more difficult time turning to pass through the orifice when the lateral velocity is high. Consequently the orifice "contractions" are more severe at high flow velocities.

There is a substantial, systematic variation in the flow through the orifices along each lateral. The variation is greater for systems having a greater number of ports, or orifices. On the other hand, the openings into the filter bed must be spaced closely enough to insure adequate dispersion of wash water throughout the gravel. Once the geometry of any manifold has been determined, design curves such as that in Fig. 1 may be prepared.

One method of improving underdrains is to use a larger number of small-diameter orifices in the laterals. This invariably results in greater head loss, but it improves the distribution of wash water. Loss of head is not a serious problem, because the amount of water used in filter washing should usually be less than 2 per cent of the total production in a well operated plant. There is, of course, no reason to waste power that could be saved through proper design.

Gravel

The gravel layer cannot be expected to operate efficiently if the underdrain system is poorly designed. The gravel, during backwashing, serves only to distribute the water from each orifice through the area served by that orifice. It is good to have as many as five layers of gravel, each several inches thick, so that variations in level during installation will not be too important, and so that the gravel will aid in distributing the wash water throughout the filter area. The layers of gravel should be so graded that the sizes vary only gradually from one level to the next. A typical set of sizes is: top layer, 10-8 mesh; second layer, 8 mesh—¼ in.; third layer, ¼-½ in.; layer, ½-1 in., and so on. The top layer must be fine enough to support the filter sand design during filtration. For a sand having an average size of 0.7 mm, it has been customary to require that the top layer of gravel be 10-8 mesh.

Although it was formerly believed that the top layer should be about 4 in. thick, in order that some would still remain even if part of the layer moved during washing, it has been found that a thinner layer serves equally well. Studies of building underdrainage and gravel packs for wells[5], indicate that there is no significant intermixing of adjacent, non-uniform layers if the median sizes of the layers differ by a factor of no more than five. It is assumed that this factor would be reduced somewhat for relatively uniform materials and that the 10-8 mesh gravel could be replaced by 8-6 mesh material with the filter sands that are now generally used.

The most recent work on the problem of gravel movement during backwashing has been done at Chicago. Experimental work on higher-density materials (normal silica gravel has a specific gravity of 2.65) is being carried out. Higher-density materials are available with specific gravities in excess of 3.00.

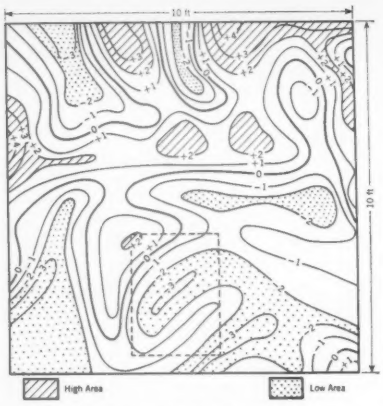

FIG. 2. Contours of Gravel Surface in Typical Filter*

*The data upon which this diagram is based were obtained by probing the filter with a sounding pole during backwashing. The contours are expressed in inches.

Filter Inspection

Routine inspection of filters should be standard practice. The inspection measures should include examination of each filter at least once a month and sounding during backwashing to see whether movement of gravel has occurred. Figure 2 is an illustration of a typical filter bed showing in detail the variation of gravel levels found by probing through the sand during backwashing with a ¾-in. wooden rod[5]. Variations in this filter are normal and may be expected in many filters. Variations greater than these may be cause for concern. It is very easy to feel the top of the gravel layer with such a rod. The rod should be so graduated that variations in distance from the water surface to the gravel surface may be measured rapidly.

A second measure for inspection of filters is sampling for mudballs. This is done by taking a sample of known volume from the top 6 in. of the bed, and screening it under water through a 10-mesh sieve. Any material that remains on the sieve (exclusive of gravel) is classified as mudball material. The percentage of mudballs by volume should not exceed 1 per cent.

An important part in the inspection of filters is observation of what occurs during backwashing in each bed. If the sand boils up in a particular filter, always at the same location, sounding will probably reveal disruption of gravel beneath the boil. Inspection of the filters may also reveal clogged masses that project through the filter bed and are evident at the surface as well as cracks in the bed that occur during filtration. The detection of the cracks usually requires drainage of the filter before backwashing. The sounding pole also reveals clogged masses, which give a soft, passive resistance instead of the "chinky" feel that gravel has.

Another way to keep track of filter bed condition is continuous monitoring of the filtered-water quality from each filter. An easy way to do this is to provide a cotton-plug unit for each filter, and to operate it at such a rate that the plug will yield good values when changed weekly. A rate of 40 ml/min should be satisfactory for turbidities up to 0.3 ppm. The cotton plugs, weighing 2 g, are ashed and the residue is weighed. The weight of residue divided by the amount of water that has been passed through the cotton plug (which is controlled by a simple float valve—orifice arrangement) gives the quanity of suspended material appearing in the filter effluent in milligrams per liter. Normally all filters should produce approximately the same amount of suspended matter in the filter effluent. Any abnormally high value is cause for inspection. It may be found that the sand in the unit is of different size than in the other filters, or that there are clogged masses, disturbed gravel, cracking, or pulling away from the sidewalls.

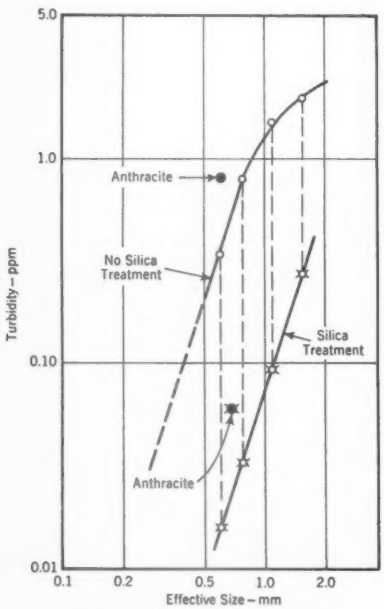

Fig. 3. Turbidity Removal With Various Filtering Materials*

*Turbidity was determined by cotton plug filter. The curve for treatment without activated silica shows that effluent turbidity from coarse materials approached that of settled water.

Filter Media

An important fact about filter media is that the quality of filtered water is dependent upon the size of openings through the bed. The larger the openings the less clear the effluent will be. In a plant where sanitary hazards are low and water has been well treated before filtration, coarse sand may safely be used. If pollution hazards are high, however, and pretreatment facilities are not completely satisfactory, finer sand is required. Sand finer than 0.5 mm is rarely used, because coarser sand will generally produce safe water with turbidities of less than 0.2 ppm, and finer material causes great trouble in short filter runs. The lengths of filter runs are directly proportional to the square of the sand size, and very fine sand may cause rapid clogging.

Most filter sands are rounded, and there is clear evidence that the rounded particles produce clearer water than angular ones. This is because the angular materials give greater porosity. It has been found that, for a given size, the porosity of rounded sands is about 43 per cent, whereas the porosity of angular sands ranges from 48 to 55 per cent.

Figure 3 is based on data collected at Chicago[7]. From the curves it can be seen that filtered-water turbidity is directly proportional to the cube of the sand size. The figure also demonstrates the difference in filter effluent quality for two flocculation conditions. Flocculation conditions are more favorable during warm weather than cold, and lower turbidities are easily obtained. For both

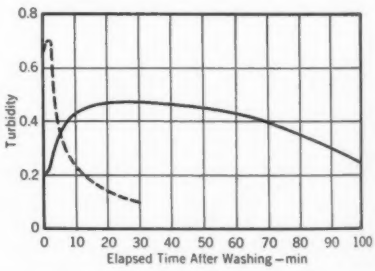

Fig. 4. Effluent Turbidity After Filter Washing*

*The rise in turbidity just after the beginning of a filter run is due to break-through of flocculated material broken up during the washing process. This turbidity cleared up much more rapidly with 0.5-mm sand (dashed curve) than with 0.9mm sand (solid curve).

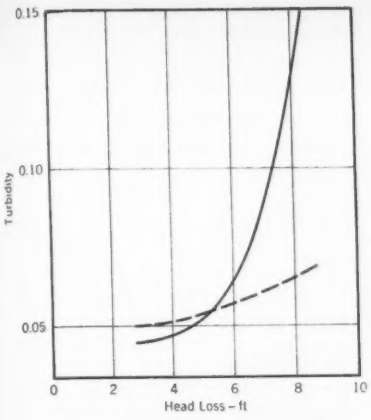

Fig. 5. Breakthrough at End of Filter Run*

The solid curve represents the increase in turbidity with head loss with weak floc; the dashed curve represents the increase with normal floc. Turbidity data were gathered with a microphotometer.

conditions it will be noted that the turbidity of the effluent from the bed of angular material was more than twice that of the effluent from the rounded-sand filters.

These results do not condemn the angular materials, which may safely be used, if a corresponding size reduction is made, with equal results. For filters of equal clarifying ability, filter runs will be approximately equal in effectiveness, regardless of porosity[8].

The use of anthracite (an angular material) has grown in recent years. Its use may sometimes be accompanied by a lowering of filter-water quality. Anthracite filtering materials are lighter than sand and therefore more subject to troubles that start at the top of the filter bed. On the contrary, they are less subject to the troubles that start at the bottom of the filter bed, because coal is much lighter in weight than gravel and there is little tendency for the gravel to move.

There is a very useful place for the light-weight angular materials as an additive to the sand bed. Several inches of anthracite of 1-mm effective size may be placed on top of a filter having a sand of 0.5 mm effective size. Under backwashing alone, the materials stay completely separate. There is some mixing when surface washes are used, but surface washing is necessary in order to offset the increased mudball-forming tendencies of the lighter-weight materials. Restratification may be obtained by a period of low-velocity upflow after the surface wash is turned off. The use of coarse anthracite on top of sand substantially lengthens filter runs.

Breakthroughs in Filters

At the start of a filter run, there is a minor breakthrough of suspended matter into the effluent. It used to be the custom to operate filters to waste at the start of the run for a period long enough to flush away this breakthrough, which may last for as much as 1½ hr, but which is usually complete in 30 min. The startup breakthrough is probably caused by floc within the sand bed that is broken up during the washing process. The breakthrough occurs whether surface wash is used or not. Figure 4 shows breakthrough curves for two filters having fine and coarse sand (0.5- and 0.9-mm effective sizes, respectively). Both filter beds were clean and in good condition. There is reason to believe that the startup breakthrough generally lasts longer with coarse materials than with fine ones. The duration of the breakthrough for the coarse material is greater than can be accounted for by the 30-mm supply of water held above the sand within the filter, and is evidence that the coarse material requires considerable time before it functions with full effectiveness. This period may last as long as 5-10 per cent of the total filter run.

Toward the end of filter runs, especially when flocculation is not strong, there may again be filter breakthroughs. An example of this is shown in Fig. 5 for a period of weak flocculation, as compared to a period of moderately strong flocculation. The data were obtained by using a continuous-recording microphotometer. It can be seen that in both cases there was a tendency for the turbidity to rise at the end of the filter runs, but that this tendency was much greater when floc was weak. This difficulty may be eliminated by earlier backwashing. The occurrence of breakthroughs at the end of the filter run may be found only by spot-checking of filters, or with recording turbidimeters, which are expensive. "A sight" well in the filtered-water reservoir may give information on the existence of a breakthrough, but will not identify the filter causing the trouble.

Breakthroughs may also be anticipated from the behavior of the relationship between time and head loss. For a constant-rate filter, it is usual for the loss of head to be virtually constant at the beginning of the filter run, and then to rise at an increasing rate throughout the filter run. This is shown in Fig. 6. Under such conditions, breakthroughs are uncommon. The shape of a filter run curve is difficult to observe from the circular charts usually used. Strip charts are far more informative. As breakthrough threats increase, the filter run curve tends to become straighter, and when it is almost completely straight, the hazard is substantial. The worst condition of all is that shown in Fig. 7, which is a severe breakthrough, in which the floc is not strong enough to be held within the filter beds, and the loss of head increases less rapidly toward the end of the filter run. Under conditions such as this, filtered-water turbidities may be nearly as high as the applied water turbidities. Data for Fig. 6 and 7 were obtained with a recording microphotometer.

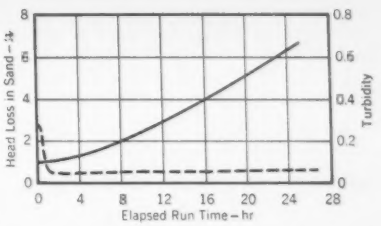

Fig. 6. Head Loss and Turbidity Removal With Strong Floc*

Comparison of the head loss (solid) curve with the turbidity (dashed) curve shows that there is a fairly constant rate of turbidity removal when the clogging rate increases throughout the filter run. Breakthroughs rarely occur under these circumstances.

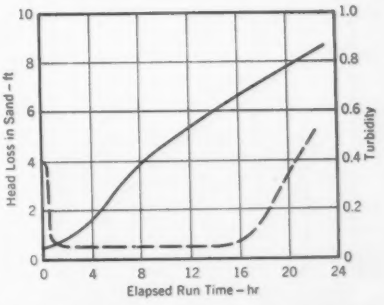

Fig. 7. Head Loss and Turbidity Removal With Weak Floc*

*The solid curve represents head loss; the dashed curve represents turbidity. The sudden rise in turbidity indicates a breakthrough, and is caused by the inability of the weak floc to remain within the filter bed. As can be seen, the breakthrough was preceded by a decline in the clogging rate.

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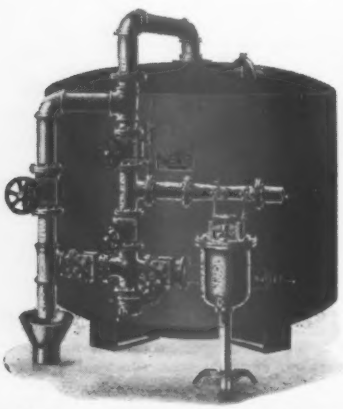

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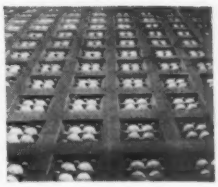

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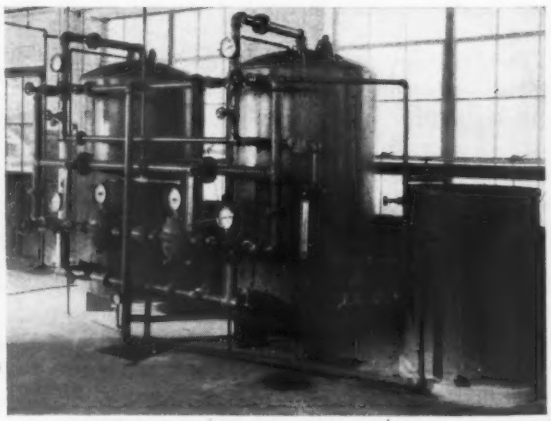

Installation of Zeolite Water Softeners

Summary

Filters should be so operated as to produce filtered water turbidities of 0.2 ppm or less. They are hampered in this aim by becoming fouled with mudballs and the troubles that grow out of mudballs. They are also hampered by inadequate wash water distribution, which may be due to disturbance of the gravel or improper underdrain design. Surface washing prevents troubles that start from the top of the bed.

Coarser sands may be safely used where there is good pretreatment, but it must be remembered that the concentration of suspended matter in the effluent is proportional to the cube of the effective size. Angular materials, such as anthracite, must be used with discretion; the adverse effects of their high porosity necessitate the use of finer materials to obtain results equal to those produced by rounded materials.

Filter breakthroughs can ruin filtered-water quality. They can be detected by frequent checking of turbidity. Analysis of filter run curves is useful in guarding against the occurence of breakthroughs.

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Reversible Diatomite Filtration

by JUDSON G. BROWN*
Wakefield, Mass.

The purification and clarification of water supplies means primarily the removal of suspended solids. The suspended solids usually found in river and lake waters consist of algae, bacteria, and silt. These solids are very fine and when filtered can form thin, slimy, impervious deposits on the septum or in the filtering medium used. In order to avoid these sealing deposits, present methods usually avoid filtration and use chemical flocculation-coagulation-sedimentation, or filtration using diatomite filter aid. The slow sand filter was the initial method employed prior to the advent of chemical treatment and the use of diatomite filter aid.

Now, in addition to these three methods, a new process called "Reversible Diatomite Filtration" is introduced as a method of purifying water. Reversible Filtration can be described as an easily cleaned variation of the slow sand filter. Its merits can best be described by comparing it with slow sand filtration.

Slow Sand Filter

The Slow Sand Filter has become outmoded due to the large area required for its installation and the difficulty in cleaning the filter bed.

Filtration

A pressure drop of 18 inches of water was considered a maximum in some European slow sand filter installations while a 4 to 6 foot head loss was considered normal in this country. When filtering algae and bacteria, the solids collected are very compressible and easily mat into a sealing layer if the pressure drop is too great.

Filtration can proceed with such a maximum pressure drop, however, as the amount of retained solids increases, the flow must be decreased to prevent a total pressure drop across the bed which exceeds the point at which the algae lattice will collapse and seal the bed. When the solids content of the raw water is low and the accumulation slow, sufficient flow can be maintained for long periods. Raw waters having concentrations of less than 40 mg/L suspended solids have been fed satisfactorily and economically to slow sand filters.

Periods up to 24 hours are required to clean the collected material from one-half acre of slow sand filters. Large volumes of water must be filtered before cleaning is required, if the process is to be economical. A prime limitation is filter cleaning.

Filter Cleaning

If a slow sand filter could be cleaned in a very short time, automatically and cheaply, the process would be economical. In addition, more turbid waters could be filtered at higher rates.

For example, if the collected solids could be removed in one minute, a total filtering cycle of 10 to 30 minutes might prove very economical. A means of removing and discharging the slimy filter collections automatically, quickly and cheaply is provided by the process described in this article.

Reversible Diatomite Filtration

Reversible Diatomite Filtration provides for the efficient complete discharge of thin filter cakes from one side of a filtering septum by using raw water feed for backwashing. The significant advantage of this backwashing method is best shown in step 3 below.

Process Described[1]

In Reversible Diatomite Filtration the first phase of the process is carried out in one direction in the same manner as conventional diatomite filtration. Diatomaceous earth is fed with the raw water forming the desired filter cake thickness on the septum or cloth while filtration continues. The feature which differs from the conventional methods comes during backwash. In reversible filtration, backwashing is accomplished merely by reversing the flow through the septum in the method described below. The pressure-type filtration unit is illustrated in Fig. 1 and explained by the following typical steps:

1. With the top, or clear discharge port, of chamber **A** (labeled valve **CA**) closed, and the bottom or sludge

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discharge port of chamber **A** (labeled valve **SA**) also closed, feed is directed into chamber **A** through the feed port (labeled valve **FA**). This pressurizes chamber **A** with respect to chamber **B**. With valves **FB** and **SB** closed, and valve **CB** open, chamber **B** is at atmospheric pressure and filtrate is free to flow out through the top clear discharge valve **CB**.

Under this condition filtration will take place through the filter septum separating chamber **A** and **B**. Cake forms on the **A** side of the filter septum, and filtrate passes into chamber **B** and out the top valve **CB**.

2. When filtration has continued as long as desired, valve **FA**, the feed valve, is closed, and valve **SA** is opened. This releases the pressure in chamber **A**.
3. Valve **CB** is closed, feed valve **FB** is opened with **SB** still closed; this pressurizes chamber **B** by forcing feed into it.

Filtration then starts from chamber **B** to chamber **A** through the filter septum separating the chambers.

As filtrate starts through the septum it acts as a backwash, discharging the cake that had been deposited on the **A** side of the cloth during the previous half-cycle when the filtration was taking place from **A** to **B** (Step 1).

As this cake is removed from the septum all flow is out the bottom valve **SA**, carrying the cake with it.

As the filtrate flows through the septum backwashing the cake in **A**, a new cake is formed on the **B** side of the septum in direct ratio to the amount of filtrate that has passed through the septum.

Where cake is discharged on the **A** side the resistance to flow is less than where cake remains on the **A** side. This results in higher filtration rates at the points of least resistance, namely, those areas where cake has been discharged from the **A** side.

At these points of higher flow, cake builds up on the **B** side faster than at points where cake remains on the **A** side. The resistance then increases at these points of higher flow, higher pressure drop results and forces the flow to those sections where cake still remains on the **A** side; forcing off the remaining cake on side **A**. This continues until all cake has been discharged. Cake continues to flow out the bottom valve **SA** until chamber **A** is clear of all backwashed cake.

4. Valve **SA** can then be closed and **CA** opened, allowing all remaining clear filtrate to flow out the top.
5. When filtration has been carried out as long as desired, the feed to chamber **B** is shut off by closing valve **FB** and the pressure in **B** is released by opening valve **SB**.
6. Valve **CA** is then closed and **FA** opened. (The cycle has now reached the reverse of step 3 shown above and continues through step 6 with all references to **A** interchanged with **B**.)

Cake Discharge

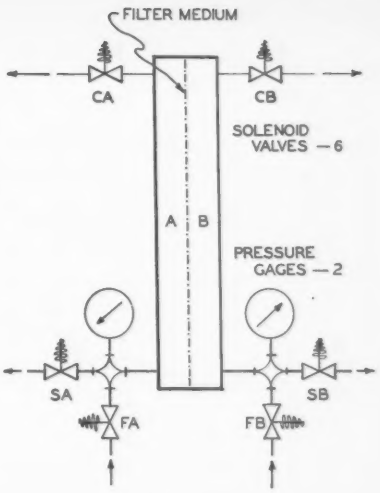
The automatic cake discharging process described above is particularly well suited for the type of solids in water supplies — the type of solids that usually are very difficult to remove and discharged from the filtering unit.

One way of removing this deposit is to dispose of the filtering medium with the deposit. This is the procedure used in the disposable cartridge type of filter, the replaceable paper pad and felt filters, the precoat filters, and the slow sand filters. Sand filters that are washed in place are a variation of this.

Another approach which aids discharging these slimy solids is to prevent their penetration into the medium. This keeps a separate cake on the surface that can be separated from the medium or septum easier. This is known as *cake filtration*. When the retained solids are mixed in with the filtering medium as in a disposable cartridge filter, the process is known as *filter media filtration*.[2]

In cake filtration the deposited cake can be peeled from the retaining filtering septum during backwash, when the pressure drop across the cake is sufficient to break the mechanical bond between the cake and the retaining septum. When a clear non-plugging fluid is used to backwash a thin slimy cake, as is the persent practice in cake forming filters, a portion of the cake will be discharged with the initial surge. Then, with a portion of the cloth cleaned, it is no longer easy to build up a pressure drop across the cake and septum to force any more cake off. This is the effective end of the backwash and over half of the cake may remain on the cloth.

The backwashing pressure drop required in order to obtain satisfactory discharging is the problem. This problem has been helped in the past in cake forming filters by the following methods:



1. Backwash only a small portion of the total filter septum at one time — this system allows the full volume of the backwash pump to work on a small area and provides a higher pressure drop over that small area. By the use of individual plate valves, one plate in a filter press can be backwashed, then sealed, and a second leaf backwashed. This operation is continued plate by plate until the filter is cleaned. This procedure is also used in a tube filter.
2. Use air pressure surge domes to increase the velocity of the initial backwash — this method holds the pressure drop, over the cloth, higher for a short period of time and improves the backwashing efficiency.
3. Use monofilament wire and synthetic fiber cloths — these greatly decrease the mechanical attachment of the cake to the septum. Therefore, the pressure drop over the septum and cake on backwashing need not be as great.

Coating Septum During Backwash

Reversible Filtration plugs the septum on the opposite side of the cloth in those areas where cake has been removed by the initial backwash surge. This new coating on the second side increases the pressure drop through the filter septum and water traveling the path of least resistance tends to force off the remaining cake. This old cake discharging and new coat plugging, continues until the cake is

completely discharged. This is similar to the step-wise plate discharging described in (1) above.

Reversible Filtration discharges a cake completely from one side of the septum and places a new cake on the opposite side in one operation. The first side of the septum is purged by filtrate all during the cake discharging period. Therefore, when the last of the cake has been discharged, the clear filtrate can be collected and filtration continued in the same direction until the new cake must be discharged by reversing the cycle.

Backwashing is automatic and quick and can be done frequently. If it is done frequently, filter cakes are kept thin and thin filter cakes mean less resistance to flow and higher filtration rates. These higher filtration rates make it economically possible to reduce the pressure drop and reduce the amount of filter aid required. If a Reversible Filter cake is 1/20 as thick as a standard cake, then 1/10 the pressure drop can be used while maintaining twice the filtering rate. In the case of diatomite filtration of water supplies, the lower filter aid requirement is very important since it is the most expensive item. Lower pressure drops are desirable for four reasons: (1) in filtering the highly compressible algae, less filter aid is required with lower head losses; (2) lower pressure drops usually give better quality filtrates; (3) power is saved; and (4) there are equipment savings.

Municipal Water Filtration Tests

In most Reversible Filtration tests to date on water supplies the above described cake discharging feature has made it possible to eliminate the use of diatomaceous earth precoat. The cake discharging feature has also allowed the economical use of less body aid but the use of some diatomite as body aid greatly increases the filtering rates and improves the cake discharging.

In raw waters having high dissolved color, alum treatment is used to remove the color. In the past, waters high in color, were usually treated most economically by flocculating and settling prior to filtration on sand filters or diatomite filters. This type of treatment has been required because of the difficulty in filtering the alum precipitate formed.

With the cake discharging feature of Reversible Filtration it has been possible to filter, economically, alum precipitated color from water without prior flocculation and settling, an operation more economical than existing or proposed rapid sand filter plants operated well below capacity.

Quality

In the experimental studies, the quality of unchlorinated Reversible Filtration effluent has been equal to chlorinated filtrate from rapid sand filter plants. In cases where the dissolved iron and manganese content is high, oxidation prior to filtration is required in both systems. Dissolved odor and taste can be reduced in both cases by treatment with activated carbon.

The high quality of diatomite filtered water is well known.[3,4] Reversible Filtration uses the low head loss of the slow sand filter plus the body aid of the diatomaceous earth filters. Thus, if the chlorination should fail, it still provides a high quality filtrate that should be furnished municipal water systems. Too many present rapid sand filter plants rely heavily on chlorine treatment, and a chlorination failure would probably produce unsatisfactory water.

It is not proposed to eliminate post chlorination at any time, but it is desirable to point out that Reversible Filtration with diatomaceous earth appears to provide a second line of defense in case of chlorination failure. This defense is not available with ordinary rapid sand filter plants. It has also been shown that diatomite filtration removes some harmful organisms that are uncontrolled by chlorination and not removed by rapid sand filter plants.[4]

Costs

Reversible Filtration has been described as a slow sand filter that uses diatomite body aid (similar to standard diatomite filters) with an automatic cake discharging procedure. An approximate comparison between standard diatomite filtration and Reversible Filtration can be shown by the use of recent data. A small portable Reversible Filter was operated in a municipal water plant which uses porous stone tube diatomite pressure filters. Both units used the same swampy lake water. The comparison is shown in the accompanying table.

The relative costs of the bare filters as presented in the table will be reasonably constant for installations of this size and larger. In 150 sq ft installations the ratio will be nearer $20 to $10/sq ft of filtering surface. Present figures indicate an installed cost for reversible filters equals about half the installed cost of pressure tube filters per unit of capacity. These more useful complete installation costs for the two systems will vary with preferences of different customers and designers.

Additional Test Data

Three other tests are described to show some of the filtration problems for which Reversible Filtration is being proposed.

City Water—Boston, Mass.

Water furnished to Boston is chlorinated but not filtered. As it is taken from the mains, it contains dead algae and the normal suspended solids in a large clear reservoir, plus the iron picked up in the mains.

One gallon of this water plugged a one square inch disk of Whatman 41 filter paper at 120°F under a constant vacuum of 11 in. of Hg after 22 minutes. A dark tan deposit was left on the paper.

In a test run this water was filtered with 140 lb of Dicalite Speed-

Comparison of Standard Diatomite Filtration with Reversible Filtration

	Porous Stone	Reversible Filter
Gal/sq ft/min	0.8	2.0
Ft of Water Head Loss	30 (avg)	4
Precoat—lb/mil gal	150	0
Body aid—lb/mil gal	400	400
Body aid—$/mil gal	$18	$18
Filter Cost Investment $ sq ft	20	5
Sq ft filter surface/3mgd	2600	1040
Filter Investment—$/3mgd	52,000	5200
Filter Dry Weight—lb/3mgd	54,000	1000
Size—cu ft/3mgd	1,200	100
Sq ft floor space/3mgd	420	54

plus diatomite per mil gal of filtrate — cost $5.60 at a delivered price of $80 per ton in Boston in car load lots of 30 tons. The portable test Reversible Filter contained six square inches of Nitex 36 nylon bolting cloth with an opening of 36 microns. An average rate of 5 gpm per square foot was obtained with a pressure drop of between 6 inches and 24 inches of water through the filter. A gallon of the filtrate produced would pass through Whatman 41 filter paper in 2 min.

The test cycle consisted of one minute to purge the cake and residual feed, and 10 minutes of clear filtrate collection. It was estimated that a 1.5 mgd filter installation for this application would cost about $2,000 for the bare filter and about $6,500 to install with piping, valves, timer, tanks, and filter aid feeder.

Later work showed that a Nitex 75 cloth with a 47 per cent open area and 75 micron openings would be better for this work. The above estimate includes this cloth in the filter cost estimate. This is a 200 sq ft filter containing 24 plates with 8.6 sq ft per plate. Each plate would be 36¼ x 41¼ x ¾ in. The port system is designed for 10 gpm/sq ft and has 0.7 sq in. of port area per 100 sq in. of filtering surface.

Merrimack River—Lowell, Mass.

A test was made on November 13, 1957 when the river water had a turbidity of 6 mg/L, a color of 48 mg/L, and iron of 0.70 mg/L. The effluent after alum and Speedplus treatment had a turbidity of 1, a color of 8, and an iron of 0.08 mg/L. The amount of Dicalite 4200 filter aid required varied from $150 and $216 per mil gal. The bacteria content was reduced, without any chlorine, from 2400 MPN to less than 3.6 MPN. All five lactose tubes (10 ml) on the raw water were positive and all five lactose tubes (10 ml) on the filtered water were negative.

A one minute purge and 10 minutes clear filtrate cycle was used. The pressure drop was from 2 to 4 ft of water. A 325 x 325 mesh, .0014 inch wire stainless steel cloth was used. A filtering rate of 1.5 gpm per sq ft was obtained.

Algae Removal

In a test on water containing 2,000,000 chlorella per ml, which are 2-5 micron spheres, the algae were concentrated by a factor of 7 at a total feed rate of 2 gpm/sq ft. Head loss was 2 ft of water using the Nitex 75 nylon bolting cloth. A mixture of equal weights of Dicalite Speedflow and Speedplus were used. Cost of the filter aid was $150/mil gal.

The objective here was to recover the Chlorella without hurting them or reducing their activity. The remaining 6 volumes of relatively algae free water were to be discarded. The filter aid was easily separated by settling from the chlorella and could be reused with probably less than a 10 per cent loss per cycle or a net cost of perhaps $15.00 per million gallons processed.[5] A 3 minute cycle was used.

Peak Load Applications[6]

In most water systems there is a considerable variation between the peak water demand during hot summer days and minimum needs during cold winter days. In the past it has been the practice to build a rapid sand filter plant large enough to handle the predicted peak demand for a ten or twenty year period. The full capacity of the plant would not be expected to be used except perhaps for one day ten or twenty years after it is built. Such a design means that the indirect charges based on the total investment must be carried by a relatively small amount of water treated. The indirect charges are the interest on the bonds issued to raise the money to build the plant, the amortization of the plant over its expected life, and maintenance charges. These three items can be figured several ways but the usual result is a cost of between 6 and 8 per cent per year of the total investment.

A recent rapid sand filter plant built for $800,000 has a rated capacity of 3.5 mgd with some extra provisions for future expansion to 5.25 mgd. During its first year of operation 229 million gallons were produced, or a utilization of less than 20 per cent of the available capacity. The indirect charges amounted to about $210.00 per mil gal produced while the direct costs for chemical, power, and labor were about $137.00 per mil gal. Total cost of the water produced in 1956 was about $347.00 mil gal.

In another municipal water department desirous of expanding its capacity from 8 to 14 mgd, a rapid sand filter plant has been proposed for the additional 6 mgd at an investment of $2,000,000. This unit would operate only during the peak demand days of the summer. It is estimated that the total production for the first three years will be 440 mil gal or about 5 per cent of capacity. These 440 million gallons will cost about $1,000 per mil gal due primarily to the indirect charges of over $800/mil gal.

This type of excessive peak demand charge exists in all variable demand cases. These indirect costs may not be known or figured, but one way or another they exist and either the water consumer or the taxpayer will pay these indirect charges as well as the direct charges.

A rapid sand filter plant is an economical way to produce city water supplies when it is operated at full capacity. However, when it is idle, the indirect charges do not stop, and the small production must carry all charges. A promising solution to this problem is to be found in the use of the low investment diatomite filters. It has been estimated that the peak demand water required in the second example above could be produced for about one-third the above costs if a Reversible Diatomite Filtration plant were used without flocculation and setting of the feed before filtration.

The relative economics between the two systems will vary as the water supply changes. In waters where alum treatment is not required for color removal the diatomite filters do much better. The entire water demand is being handled in some cases more economically with diatomaceous earth filters than would be possible with rapid sand filter plants. In the second case above where 6 mgd of peak demand is needed, a very dirty raw water is to be used and alum treatment is required. In this case the rapid sand filter plant would be cheaper than the Reversible Filter if it were used, as an average, at more than about 15 per cent of capacity.

A third system may be considered where dissolved color is involved. This system includes flocculating and settling prior to diatomite filtration as used in the portable potable emergency water supply systems, it has the disadvantage of the large flocculating and settling equipment but will require much less filter aid.[6]

Present data indicate that in many cases a rapid sand filter plant should

be sized so that it is just big enough to handle the average demand and can, therefore, operate all year at near its full capacity. The peak demands, however, could be handled in these cases by low investment diatomite filters. The team of the two systems should provide the cheapest water.

The proposed team of two systems should be particularly helpful in the expansion plans of existing water works departments. The small size of the Reversible Filter should make it possible in many areas to install the needed additional capacity in existing buildings. This low investment proposal will apply particularly well to summer resorts and fire fighting where exceptional peak demands are encountered for short periods.

Comment and Criticism

Before submitting this article for publication, the author submitted it to three reviewers: Robert H. Culver of Camp, Dresser & McKee, Cons. Engrs., Boston; R. Zadigan, of Great Lakes Carbon Co., Buffalo, N. Y.; and G. R. Bell of Johns-Manville Research Center, Manville, N. J. Many of their suggestions were incorporated into the manuscript; a few seem to be controversial. Excerpts from the reviewers' comments follow:

ROBERT H. CULVER—" . . ., the introduction of raw water on both sides of the filter is a doubtful public health practice. It is well known that bacteria adhere to the walls of pipes and tanks and grow and multiply thereon. If they come in contact with both sides of the filter septum, contamination of the filtrate cannot be prevented."

"In regard to removal of color by alum treatment it is generally considered necessary to provide flocculation to promote the adsorption of the color by the coagulant particles as well as to develop particles large enough to be removed by settling. You have given no evidence that this procedure is not equally necessary when using Reversible Filtration."

R. ZADIGAN—"I question the advisability of diatomite filtration of alum treated water without settling."

G. R. BELL—"The heart of the process is, of course, the ability of the filter to backwash cleanly, completely and quickly. If it does not backwash cleanly, there is a progressive loss of filtering surface leading to eventual outage of the filter. If it does not backwash completely the chance of filtered liquor contamination is serious. If it does not backwash quickly, the ratio of wash losses to production is prohibitive from an economic standpoint."

"This process appears to provide adequate means for accomplishing each of these important phases of the operation."

"The process, while lacking large scale field tests, would appear to have immediate applicability to industrial and other water supplies needing the quality of diatomite filtration."

"Its application to potable water supplies appears to face a long period of evaluation because of the potential contamination of the filtered water with the cake from the previous half-cycle. Health officers properly take the safety of the consumer as the ultimate criterion for any water purification process."

"It is to be hoped that an actual installation of sufficient size to give real cost figures can soon be made. The writer is well aware of the pitfalls of scaleup from pilot plant to operating equipment. Plant-scale equipment is expensive, both for the basic filter and accessories, and for their installation. Thus, for example, a 6-in. gate valve costs about twice as much as a 4-in. one does. Make them automatic and the ratio may be 4 to 1. Other accessories are similarly scaled up so that the savings which may result from larger filters are quickly eaten up by other costs."

"Similarly, the actual costs of operation must be obtained from large enough equipment over a sufficient period of time to evaluate such factors as applicable ranges of turbidity, amount and type of filter aid required, and probable maintenance costs. In addition to costs, such an operation with proper records will do much to establish the reliability of any new type of filter."

Author's Closure

With respect to contamination of both sides of the filter, while it is true that in the reversal process the feed chamber is purged and then used as the filtrate collecting chamber, the point to remember is that the amount of this contamination must be considered in relationship to the amount allowed to pass through the filter. If a suspended solids removal equivalent to the separation obtained in a rapid sand filter plant is desired, then all data to date indicate that "filtrate chamber contamination" will not be a factor.

Reversible Filtration, because of the low head loss used and the finer grades of filter aid that can be used economically, has produced even better filtrates in tests than present diatomite filters as currently operated. It is only when producing such filtrates that "filtrate chamber contamination" might become a factor. There is not sufficient data accumulated to date to indicate at what point this will become a factor.

With respect to removal of color by alum treatment, there is the belief that unprecipitated organic acid color is adsorbed on the alum floc, and that alum floc must grow first to adsorb the color.

I believe that the problem here can be resolved by first defining carefully the terms that are used. The question is what are suspended color, precipitated color, dissolved color, and unadsorbed color. The point is that there is no sharp line that can be drawn between a suspended color and a dissolved color.

If one wishes to split the color producing material into two groups according to particle size and label one group suspended and the other dissolved, then the splitting method must be defined. One procedure is to define the mechanism used to separate the two fractions. Perhaps such a standard exists but has been largely forgotten. A suitable procedure is to use a Whatman 41 filter paper with 11 in. Hg vacuum at 60°F. Any value obtained in this manner, however, has little bearing on the amount of color removed by a slow sand filter, a pressure diatomite filter using Dicalite 4200 (coarse grade) at 50 psi pressure drop, or a Reversible Filter using Speedplus (medium grade) at 2 psi pressure drop.

One test on the Concord River water at Billerica, Mass. showed a total color of 36 mg/L. A laboratory filter paper test showed a dissolved color of 20 mg/L. A Reversible Filter filtrate using Speedplus at 2 psi pressure drop showed a color after filtration of 10 mg/L, indicating a removal of dissolved color.

The question of color adsorption on an alum floc can perhaps be bet-

ter understood if it is approached from the view that all color consists of particles of various sizes. The finest particles are said to be in solution. When alum is added, the particles immediately begin to coalesce and grow into larger particles or flocs. This growth process is a continuous process and can be continued until the floc is large enough to settle out of water. Some of the smaller floc can be stopped in a coarse sand filter. Some of the still smaller coalesced particles, which might not be called floc, can in turn be stopped by coalescing with floc already in the sand filter or actually filtered out by the floc in the sand filter.

The amount of retention time required after alum addition is a function of the size of the particles required for the separation process used. In Reversible Filtration a very fine particle can be retained and therefore very little retention time is needed. In the tests to date, the minimum retention used has been about 5 minutes after good agitation. Total colors of 40 to 70 mg/L containing 25 to 35 mg/L of so-called dissolved color have been reduced with alum to readings of 1 to 2 mg/L in more than 30 different tests at different seasons on 5 different supplies. Lower retention times will be evaluated on larger equipment. With respect to the advisability of diatomite filtration of alum treated water without settling, it is true that in precoat filters it is uneconomical to filter alum treated water without pre-settling. This fact is true because the cycles become so short that the labor and precoat costs become too great. Both of these costs have been eliminated in Reversible Filtration. The body aid requirement is also greatly increased by filtering all the alum floc in both systems.

Pre-settling of the alum floc can be used with Reversible Filtration just as it is in some present diatomite pressure tube and leaf systems. The objective to date has been to show that Reversible Filtration reduces the cost of filtering without pre-settling to the point where the elimination of the expensive flocculating and settling equipment must be considered.

Every installation must be evaluated separately. In emergency applications or extreme peak load situations where capacity will be idle more than 95 per cent of the time, it appears now that alum precipitated color should be filtered without flocculation and settling equipment. This situation is economically described in one of the examples in the paper.

The author appreciates the comments of the reviewers. Since Reversible Filtration is in the early stages of development, additional tests, evaluation and discussion will be required. Comments of readers will be helpful.

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Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthrafilt and sand and saves on freight and handling charges.

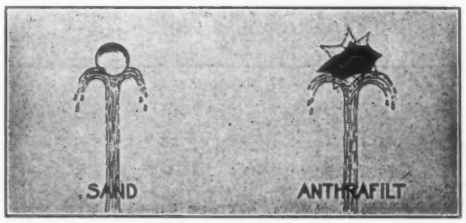
Filtration Characteristics

Anthrafilt granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. The uniformity coefficient is less than 1.75 in all sizes. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

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Increased capacity with same plant
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When Used in Existing Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

Availability of Fluoridation Chemicals*

A Joint Discussion

Cost and Production

by MAX C. METZIGER

Director of Research & Development, Blockson Chemical Co., Div. of Olin Mathieson Chemical Corp., Joliet, Ill.

When fluoridation of drinking water was first investigated on an experimental basis, the only chemical that was thought to be suitable and safe to use was sodium fluoride. As a broader fluoridation program was envisaged, however, it was immediately apparent that the supply of sodium fluoride would be inadequate, and that its cost would be too high. In order to be economically feasible the fluoride had to be derived from sources other than hydrofluoric acid and fluorspar. The phosphate industry offered the largest and most economical potential source of fluoride chemicals.

Table 1 shows the relative costs of the fluorides, compared on a fluorine-content basis.

Table 1
Cost of Fluoridation Chemicals

Fluoride	Cost cents per lb	Fluorine Content per cent	Cost of Fluorine cents per lb
NaF	13.5	45.2	29.9
Na_2SiF_6	6.5	60.6	10.7
H_2SiF_6*	2.7	18.6	14.5
HF	21.0	95.0	22.1

*23.5 per cent solution.

Fluorine Evolution

Phosphate rock is essentially fluoroapatite, a complex salt of tricalcium phosphate and calcium fluoride. The average fluorine content of a high-grade rock is approximately 3.5 per cent. Although small as a percentage, this fluoride constitutes an enormous reservoir of potential fluorine because of the large amounts of phosphate rock used in agriculture and industry. In 1957 approximately 15,000,000 tons of phosphate rock were mined, which represents more than 500,000 tons of fluorine. Approximately two-thirds of the rock was used in the manufacture of fertilizer and wet-process phosphoric acid. Hill and Jacobs[1] estimated that an average of 27.7 per cent of the fluorine is evolved in the manufacture of fertilizer. Based on this estimate, the amount of fluorine evolved in fertilizer plants is 97,000 tons. Unfortunately, only a small portion of the fluorine evolved is now being recovered, mainly because many of the fertilizer plants are so small that recovery is not economical. According to Hill and Jacobs 53 per cent of the single superphosphate comes from plants where average production is less than 50,000 tons annually, and only 270 tons or less of fluorine is evolved. The trend, however, in the fertilizer industry is toward higher-analysis products. This requires increasing amounts of triple superphosphate and phosphoric acid. The proportion of fluorine evolution from triple superphosphate operation is considerably higher, because in addition to the den gases a considerable amount of fluorine is evolved during the evaporation of phosphoric acid, which will increase the potentially available by-product fluorine. In Florida alone the total capacity of triple superphosphate has been increased by approximately 1,000,000 tons per year.

It is estimated that in 1958 approximately 35,000 tons of hydrofluosilicic acid will be recovered. Most of this acid is at present converted to sodium silicofluoride and used by the aluminum industry in the production of cryolite. A number of new wet-process phosphoric acid plants have also been put in operation in the middle west in the last 2 years, a possible new source of fluoride chemicals.

Silicon Fluoride Recovery

When phosphate rock is treated with sulfuric acid to form phosphoric acid or superphosphate the fluorine is volatilized largely as silicon fluoride, silica being present as an impurity in the phosphate rock. Two processes are used for recovering silicon fluoride in the phosphate operations:

1. *Recovery in the manufacture of superphosphate fertilizer.* In the manufacture of superphosphate fertilizer, phosphate rock is reacted with sulfuric acid or phosphoric acid to form essentially monocalcium phosphate. The fluorine released as hydrofluoric acid reacts with silica to form silicon tetrafluoride SiF_4. The gases are absorbed in water to form hydrofluosilicic acid in accordance with the following reactions:

$$4HF + SiO_2 \rightarrow SiF_4 + 2H_2O$$
$$3SiF_4 + 2H_2O \rightarrow 2H_2SiF_6 + SiO_2$$

The hydrofluosilicic acid is recirculated until a 15-20 per cent solution is obtained, purified, and evaporated to the desired strength. If the sodium salt is desired, the acid is treated with sodium chloride:

$$H_2SiF_6 + 2NaCl \rightarrow Na_2SiF_6 + 2HCl$$

The sodium silicofluoride is separated by centrifuging, drying, and screening to the desired specification.

2. *Recovery of fluorine from phosphoric acid.* Phosphoric acid is manufactured by the wet process with the following reactions:

$$Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow 3CaSO_4 + 2H_3PO_4$$
$$2CaF_2 + 2H_2SO_4 + SiO_2 \rightarrow 2CaSO_4 + SiF_4 + 2H_2O$$

In this process most of the fluorine will be found in the phospheric acid as hydrofluosilicic acid. This can be recovered during evaporation as previously mentioned, but it also can be directly precipitated in the acid as

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Table 2
Fluorine Production*

Year	Production—long tons Na_2SiF_6	NaF	HF
1951	15,636	6,122	43,660
1952	12,686	3,992	41,512
1953	16,816	5,401	51,845
1954	19,783	4,721	54,968
1955	19,928	5,871	66,637
1956	20,456	5,798	75,500
1957†	—	—	77,417

*Source of this table is Ref. 3.
†Eleven months.

sodium silicofluoride by reacting with Na_2CO_3.

The process normally used in the sodium phosphate industry is:

$$H_2SiF_6 + Na_2CO_3 \rightarrow Na_2SiF_6 + CO_2 + H_2O$$

The solids are separated by centrifuging, drying, and screening. In this process from 50 to 75 per cent of the fluorine can be economically recovered as sodium silicofluoride. Hydrofluosilicic acid cannot be recovered as such, because it cannot be separated from the phosphoric acid by any practical means.

Uses and Production

There are a number of established uses for sodium silicofluoride. The supply of this product is, therefore, influenced by market conditions in certain industries. Some of the most important applications of sodium silicofluoride are: fluoridation of municipal water supplies, laundry sour, opacifier in glass manufacturing, vitreous enamel, beryllium and zirconium metallurgy, bactericide, fungicide, insecticide, termite control, preservative, mothproofing agent, and gelling agent in the manufacture of foam rubber.

Consumption of fluoride chemicals in water fluoridation was estimated[2] for 1957 to be:

Fluoride	*tons*
Sodium silicofluoride	8,000-10,000
Fluosilicic acid, 25 per cent	7,000- 8,000
Sodium fluoride	1,500- 1,600

Production of the fluorine chemicals that are normally reported to the US Bureau of Census are summarized in Table 2.

The phosphate industry is now and will continue to be the main source of fluorine chemicals for use in water fluoridation. Only a small fraction of the available fluorine is now being recovered, but recovery is steadiy increasing. This is due mainly to increase in size of production plants, the expanding triple superphosphate industry, and the increasing use of phosphoric acid in fertilizer manufacture. The quantities of fluorine available in the phosphate industry are very large, but more technological developments are needed to prevent waste of this important natural resource.

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Need for Increased Supplies

by OSCAR GULLANS

Chief Water Chem. Engr., South Dist. Filtration Plant, Chicago, Ill.

The increasing use of fluorides in water treatment, along with the increased demands for fluorides by the chemical and aluminum industries, has recently given reason for concern for future requirements of this material. The city of Chicago has not been able to obtain sufficient hydrofluosilicic acid for its current needs in the water fluoridation program. Contracts for 1958 indicate that the supply will be less than it was in 1957, when the city was able to obtain only 60 per cent of its requirements.

Present and Future Requirements

A look at the current fluorspar market[1] reveals the following: of the fluorspar production in 1957, 270,000 tons went into steel production, 110,000 to aluminum, 210,000 to chemicals, and about 70,000 tons to ceramics; the federal government purchased about 230,000 tons for stockpiling. Of the total requirements, domestic sources supplied 325,000 tons and some 620,000 tons came from abroad, two-thirds from Mexico, and the rest from Spain, Germany, Canada, and Italy.

With the increasing use of fluorides by the chemical and aluminum industries, it is estimated that they will require an additional 150,000 tons by 1965. Market projections also indicate that other consumption of fluorine chemicals, much of which will go into atomic power projects, will require a further increase of 305,000 tons per year.

New Sources

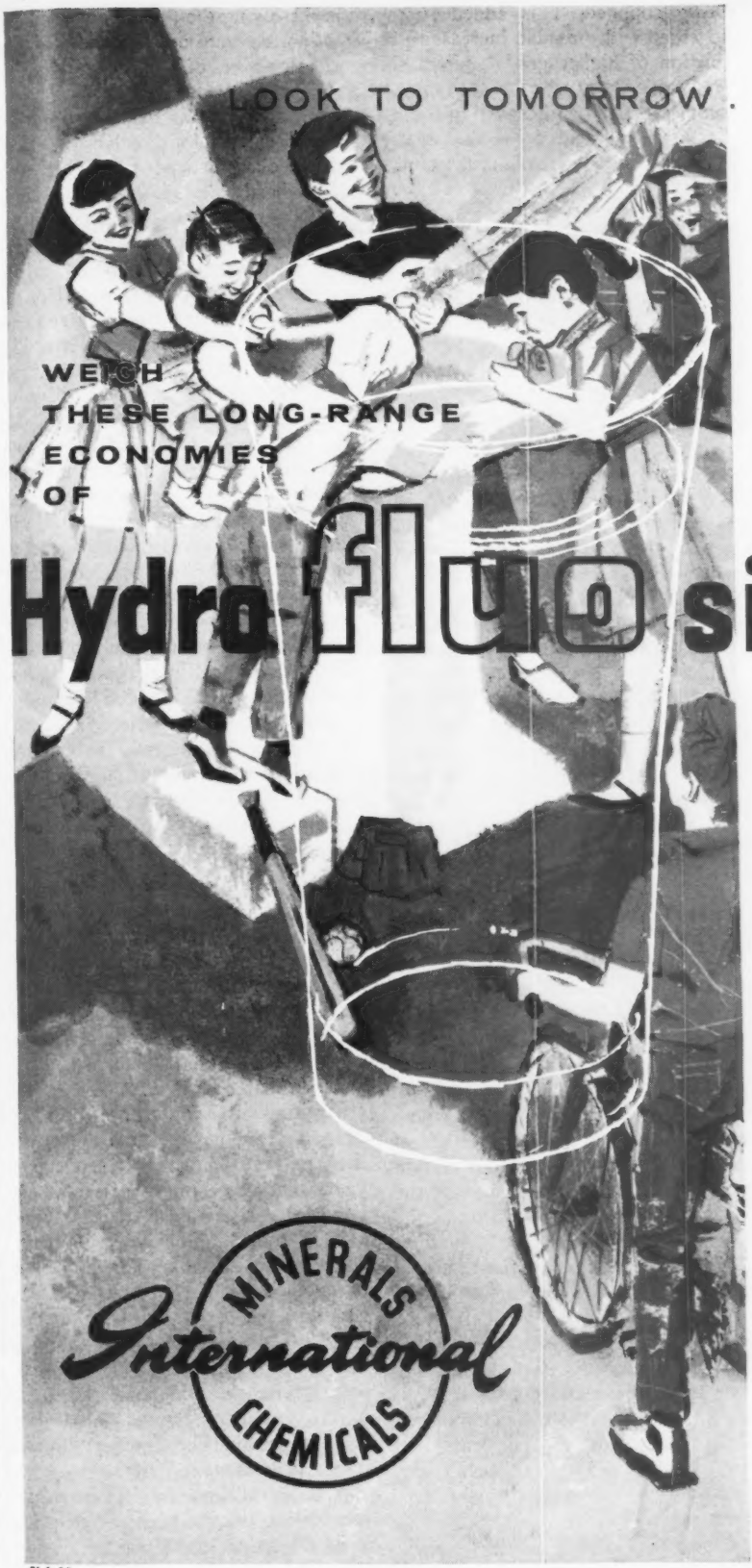
With limited supplies and reserves available (35,000,000 tons) consumers are beginning to wonder how long supplies will last, and producers are beginning to examine the possibilities of phosphate rock. Since the only commercially worked deposit of natural cryolite is on the island of Greenland, some aluminum producers are making synthetic cryolite in order to decrease their dependence on the use of imported material.

The possibility of obtaining larger supplies of fluorine from phosphate rock processors seems to be the best solution. The rock processors scrub hydrofluoric and hydrofluosilicic acids from their waste gases, and throw most of them away. Processors are now becoming interested in ways of changing this waste to profit. At the present time they cannot compete with fluorspar, either domestic or imported. If the demand for fluorspar increases as predicted, however, a combination of increased prices and improved technology to reduce recovery costs will permit the rock processor to enter the market.

It has been predicted that almost all of the fluorine for the chemical and aluminum industries (substituting for 500,000 tons as fluorspar) will someday be recovered from phosphate rock, rather than from fluorspar. This development may take place within anywhere from 5 to 25 years.

Shortages

Aluminum companies are now contracting with phosphate-rock processors to buy waste silicofluorides from which they can make synthetic cryolite or aluminum fluoride, to be used in their reduction-process baths. Under a new process it takes about 75,000 tons of cryolite to produce 1,000,000 tons of aluminum. One large aluminum producer recently contracted for 12,000 tons of hydrofluosilicic acid, 100 per cent basis, in any concentration from a 5.10 to a 30 per cent solution. This is equivalent to withdrawing 48,000 tons of hydrofluosilicic acid, 25 per cent basis, from the available market in a single year.



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Further demands of this kind can be expected, as a consequence of the expansion of aluminum production. With most of the fluorine from phosphate rock processors going to the chemical and aluminum industries, the chances of obtaining hydrofluoric or fluosilicic acid for water treatment will rapidly become smaller and smaller.

From this, it is easy to see why Chicago has had difficulties in getting its annual requirement of 7,500 tons of hydrofluosilicic acid, 25 per cent strength. The city obtained about 2,450 tons for use at the South District filtration fluoridation stations in 1957[2], which was almost the plant's annual requirement, but the Central and North District plants were only able to obtain 2,700 tons, an average of 60 per cent of their total requirements. The total amount available to the city on 1958 contracts is 3,550 tons, of which 2,000 tons is allocated to the South District Plant. This is considerably less than the amount supplied in 1957, and only a little over 50 per cent of the city's current requirements. Chicago will, therefore, be required to look to other sources for sufficient material to carry out its fluoridation program. Since sodium silicofluoride seems to be more readily available, and is the cheapest of the three water fluoridation chemicals, the South District Plant is now experimenting with the possible use of this material. As soon as the equipment can be installed for handling, all of the hydrofluosilicic acid that is available to Chicago will be diverted to the North and Central Districts. It is hoped that the supply of the sodium silicofluoride will remain available for the city's needs.

It has been recommended that the present limits of 98 per cent purity for sodium silicofluoride be reduced to 95 per cent, in order to have more of this chemical available. There is a considerable quantity of 95 per cent material from the Florida rock processors. The additional 3 per cent contamination consists of small amounts of gypsum, calcium fluosilicate, and phosphates, all of which are fairly soluble in low concentration. Laboratory tests indicate that the presence of these impurities improves the solubility of the fluoride. It is expected that the price for such material would be prorated with the current price of 98 per cent material now being supplied. This added supply, together with possible increased production of higher grade sodium silicofluoride, can probably be used to supplement the withdrawal of the hydrofluosilicic acid from the market in the southeastern area of the United States.

Imported Supplies

There has been some increase in imports of the silicofluorides from Holland and Japan. These imports have been of varying quality, and great care must be exercised in applying specifications that will guarantee the user a product of good feedability. Some of these materials have been used largely in Canada and in a few eastern cities where they can be delivered by ocean freighters. Samples of these materials indicate that they are of a fine crystalline structure, and yet are free from fines, which makes them readily feedable and free-flowing. One plant superintendent claims that it is cheaper to buy this material which is shipped 3,000 mi. by boat, than to ship the same material 300 mi. by truck or rail. American processes of manufacturing sodium silicofluoride do not readily lend themselves to the manufacture of the crystalline material without considerable added cost.

Experiments

With these considerations in mind, Chicago water utilities are experimenting with the pelletized silicofluoride developed by a local manufacturer to see if it can be adapted to a simple feeding system. In addition to the use of saturator tanks, where water is percolated through 10 ft of pellets, the city is trying certain additives to the water to increase the material's solubility and cut down the amount of water required. Sodium silicofluoride is only slightly soluble in water, and it takes about 35 gal of water to dissolve 1 lb of the fluoride at ordinary temperatures. Solubility is better with warm water, but then there is the added cost of heating the water. A weak solution of aluminum sulfate (7½ per cent solution) shows promise of being the best additive for dissolving the silicofluoride.

Chicago is also planning experiments with other compounds that may be readily adaptable for helping to dissolve the material. Experiments in dissolving the finely powdered silicofluoride were not successful, due to a carry-over of the finer materials even at low up-flow rates in a saturator tank. It has also been learned that attempts to dissolve the powdered or pelletized material with fairly hard water, 170-255 ppm hardness, were not successful, due to the formation of a coating of calcium fluoride on the granules or pellets which rendered them almost insoluble. As soon as these experiments are completed the results will be published.

The Chicago water utilities have also tried experimentally to dissolve finely powdered fluorspar, available from mines in southern Illinois, with various concentrations of aluminum sulfate solutions, by a method recently published. The material will dissolve rather slowly, and the amount of stirring and dissolving equipment that would be required to supply the amount of fluorine needed would run the cost above that for silicofluoride. There is a type of fluorspar being imported from Mexico which lends itself more readily to this dissolving method, but the freight rates to Chicago might make the cost prohibitive.

Recommendations

In adition to the current study on availability of fluorides being made by AWWA it would be well for some federal agency to investigate the current fluoride market, and the future availability of these materials. Often, only 50 per cent of Chicago's requirements are available, and there is no alternative but to turn to other types of material. It becomes a rather frustrating situation when a considerable sum of money is spent for equipment only to find at the end of 2 years that the equipment is obsolete because that particular type of fluoride is no longer available. Perhaps some type of allocation system should be adopted, similar to that for chlorine during World War II, to assure the water utility industry its share of this essential chemical. Permission to contract for these materials on a 2-, 3, or 5-year basis instead of a 1-year basis might give the supplier and the user a little more security.

A large midwestern city, currently considering the use of fluosilicic acid, is investigating other sources of fluorides in anticipation of a dwindling acid supply. Chicago will also be asked to recommend the type of fluo-

ride equipment to be installed in its new Central District Filtration Plant within the next year. Current investigations in the best material to use, its availability, and a simplified method of processing and feeding the material will, therefore, be given top priority. Any suggestions or ideas on new methods of processing or feeding fluoridation chemicals, in order that Chicago's fluoridation program may be continued, will be welcome.

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Survey of Fluoride Availability

An AWWA Staff Report

At the request of a prominent water utility official, who was experiencing difficulty obtaining a continuous and adequate supply of fluosilicic acid, AWWA surveyed the manufacturers and jobbers to learn the status of the supply of this chemical as of: [1] Mar. 1, 1958, [2] Jul. 1, 1958 and [3] Jan. 1, 1959. The questionnaire, mailed on Feb. 25, 1958, was enlarged to include sodium fluoride and sodium silicofluoride. The questionnaire was sent to a total of 34 companies and answers were received from 22. The questionnaire consisted of only three questions:

1. What is the status of the availability of fluoride chemicals used in water supplies?
2. Is your company a manufacturer or jobber of these chemicals?
3. Are you an importer?

Status of Supply

Question 1 requested the status of the supply of the three chemicals. It asked if each of the chemicals was in "Ample" or in "Short" supply.

Ample. Ample was defined as a sufficient supply of the chemical in stock or available to permit the supplier to fill orders from established customers promptly and to accept and fill new orders promptly.

Short. Short was defined as a supply which would not permit the prompt filling of the requirements of old customers or the acceptance of orders from new customers for prompt delivery.

Table 1 gives the results of this survey.

The data in Table 1 lead to the following conclusions: sodium fluoride, supply ample; sodium silicofluoride, supply ample; fluosilicic acid, *supply critical.*

Manufacturers' Comments

Comments made by four manufactures of fluosilicic acid, to explain the reasons for the critical supply, should be noted:

Manufacturer 1. Material is available for customers with whom we have contracts, and we have been taking on some additional small accounts. We have plants at which this material could be made available, but, due to the capital expenditure required, it is necessary that we have a 3- or 5-year contract before we would feel justified in putting in the necessary equipment.

Manufacturer 2. If there is a shortage of fluosilicic acid, it probably stems from the fact that most water works buy on a short-term basis. It takes a considerable investment to install facilities to filter and concentrate the weak acid to a grade suitable for fluoridation. Unlike sodium silicofluoride and sodium fluoride there is no industrial market for this acid, except a special one in Florida. Consequently, companies generally might hesitate to make the investment to produce acceptable acid on the basis of a 1-year contract, since they would not be sure of an outlet after the first year.

My guess is that water works desiring to use fluosilicic acid can find adequate sources of supply if they can find a way to make at least their initial contracts for a period longer than a year.

Manufacturer 3. At present, there is a shortage of the acid. The main reason unquestionably is that producers who would in a position to recover the acid in their operations have been rather reluctant to spend the money on the necessary equipment. This equipment is very expensive and, therefore, could only be installed profitably if the producers would have the assurance of continued business.

You are probably aware of the fact that, unfortunately, the bulk of the municipalities are buying their material on a spot basis against public bids or, in some cases, against yearly contracts. A large percentage of these municipalities, according to their regulations, will give the business to the lowest bidder regardless of how much their interests may be affected. By staying with one supplier, the municipality would have a reasonable assurance of obtaining a continuous supply.

A certain number of producers who produce the acid, or could produce it, feel that their interests would not be protected sufficiently by going through the expense on equipment without a certain amount of assurance that they will continue holding this type of business for a number of years.

Table 1
Status of Fluoride Supply

Fluoride	Status of Supply, as of	Answer Ample	Answer Short
Sodium fluoride	Mar. 1, 1958	11	0
	Jul. 1, 1958	10	1*
	Jan. 1, 1959	9	1*
Sodium silicofluoride	Mar. 1, 1958	15	1
	Jul. 1, 1958	14	1*
	Jan. 1, 1959	13	1*
Fluosilicic acid	Mar. 1, 1958	6†	2
	Jul. 1, 1958	6†	2‡
	Jan. 1, 1959	5	3§

*Questionable.
†One supplier states that he is prepared only to accept additional orders in 50-gal quantities. A second supplier will accept additional orders from small communities.
‡One supplier states that, due to seasonal cycles, he will probably be in short supply at midyear.
§Two questionable.

We believe, in all sincerity, that if some of the large municipalities would agree to contract for this material on a, let's say, 3-year basis, some of the producers would be more than willing to extend their facilities.

Manufacturer 4. A few remarks are necessary regarding our position on fluosilicic acid in a number of our plants but it is all either captive or under contract for industrial use on a "when available" basis. Considerable advance preparation would be necessary for us to offer fluosilicic acid for water fluoridation from any given plant. We would have to install purification equipment and make arrangements for transportation by tank truck. We are not particularly interested in small-package business and feel that the additional cost involved in packaging the acid would overprice it in comparison with the dry fluorides, particularly sodium silicofluoride.

Thus, a typical situation in which we might consider taking on fluosilicic acid would be where we were approached by a large city, close to one of our manufacturing plants, which would give us 3-6 months to get ready, and then some reaonable assurance that we could continue to keep the business.

Summary

This fluoride survey indicates that ample stocks of both sodium fluoride and sodium silicofluoride are available at present and for the immediate future.

Fluosilicic acid is in critical supply, at present, and may continue to be so in the near future. Only for small users does the supply seem to be ample. The present concensus of manufacturers appears to be that an ample supply of the acid can be made available for large users also, if the contracts for the acid are for a long enough time to safeguard the investment in additional plant which would be required to manufacture the acid.

Metropolitan Sewage Facilities

by RALPH E. FUHRMAN,

Exec. Secy.-Editor, Federation Sewage & Industrial Wastes Assn., Washington, D. C.

■ STANDARD METROPOLITAN AREAS number 168 according to the 1950 U. S. Census. Such an area is defined briefly as an area containing at least 50,000 persons with a population density greater than 150 persons per square mile. Boundaries are always county lines. These areas cover 7 per cent of the area of the United States but have 57 per cent (85,000,000) of the population. In size, they range from Laredo, Texas (56,000) to New York City (12,900,000).

In the five years between 1950 and 1955, 97 per cent of the nation's growth took place in these areas, and this tendency continues. The 1950 Census showed 16,120 units of government and 2,898 special districts in the 168 Standard Metropolitan Areas. When totaled, these give each area an average 113 governmental units or districts. Is it any wonder that complex situations arise when a common aim is sought?

The growth of these areas is now proceeding at a rapid rate. The modern metropolitan area continues to grow in spite of city and sometimes state boundaries. Socially and economically, the communities are one, but politically they may be quite heterogeneous.

To the Civil Engineer viewing the area from the standpoint of drainage areas, the problems of providing sewer service seem relatively simple at first. This is so from the physical standpoint, but from legal and financial obstacles he soon encounters, the situation may become complex and uncomfortable.

It has been reported that American families have reached a total of 50,000,000. Also in recent months the figure has been given that there are 13,000,000 septic tanks in the United States. On the assumption that the septic tanks are individual household units, 26 per cent of the households in the United States are being served by these tanks.

Sanitary Engineering Problems

The civil and engineering problems created by this fringe growth are manifold. The sanitary engineer is trying to provide the suburbanite with freedom from sewage disposal difficulties.

The person leaving a urban area for an underdeveloped suburban area gives waste water disposal virtually no thought. But even in the pleasant life of the suburbs, the problems of sewage disposal may soon become the main topic of neighborhood conversation. A primary problem of the engineer is to give sound advice on what plan of sewage disposal will give lasting and economical satisfaction to the area. In the city and densely populated fringes, sewers would probably be easy to finance. In the outer fringes, the problem becomes one of choice of individual household disposal or community sewers, with cost an important factor.

Septic Tanks

Recent years have found the septic tank for individual household use, a subject of several studies. In areas with a high ground water table or impervious soil its use is out of the question. A properly designed and maintained tank can still serve isolated dwellings as long as the soil will assimilate the tank effluent. Unfortunately septic tanks are generally built to good standards but the householder has no interest in sludge removal. Sludge removal can easily put off one year, then two, and so on until the absorption field is clogged. Replacement of this field is a costly and unpalatable job.

Usually at this point the homeowner becomes a most ardent supporter of a community sewer system. He may also reach this position by not exercising care in water use. If he has his own well, he is naturally sparing with water use and the absorption field works nicely. With a community water supply he uses water more freely. Absorption fields may be overloaded causing effluent to come to the surface — a nuisance and health hazard. This would point to a requirement for community sewers where community water is served.

It is impossible to state accurately the population density that could have public sewers at approximately the same cost of septic tanks. The metropolitan area density figure of 150 persons per square mile seems well below such a limit.

Cost Analysis

If a single household septic tank and disposal field costs $200, and lasts 20 years, the cost is $10 per year plus a similar figure for sludge removal, or about $20 per year. The cost of septic tanks has been reported as varying from $150 to $500.[1] Some estimate a life as short as ten years. A service sewer for a 100 ft frontage at $5 per ft can be constructed so that it will last for at least 50 years, or $10 per year. Sewer service charges of $10 per year would equalize the cost for other services, including treatment. With lots 200 feet deep, streets 60 feet wide, blocks 400 feet long and 4 persons per house, the population density would be about 4,000 per square mile. These costs seem to be equivalent, but often there is a vast difference in satisfaction to the resident.

In suburban Kansas City[2] a general demand for public sewers was voiced when the population density of 1.5 per acre or approximately 1,000 persons per square mile was reached. A population density of 2,000 per square mile or more would find community sewers the most economical as well as the most satisfactory, even if the area is well suited for subsurface disposal of septic tank effluent.

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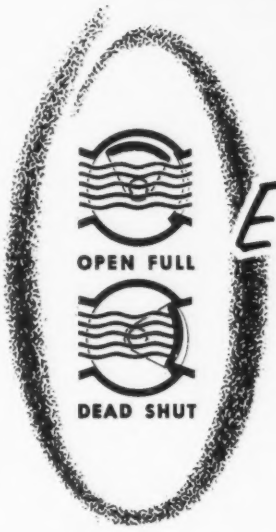

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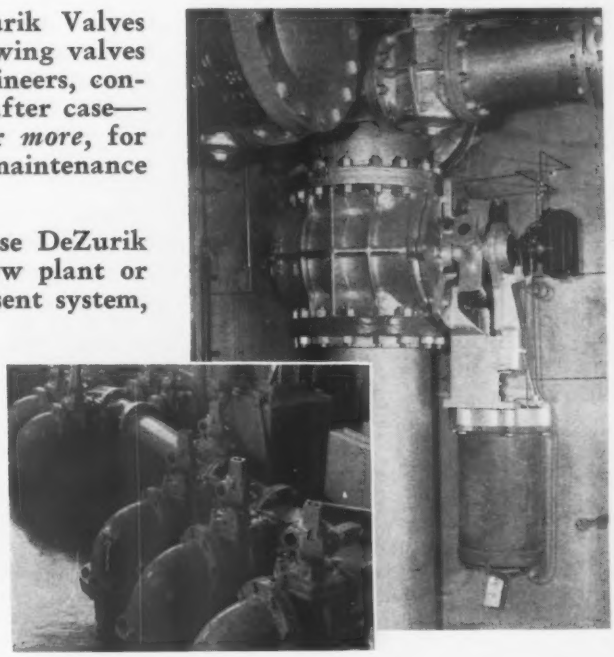

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Metropolitan Authorities

During the period of genuine advance of sanitary science in the United States, there have been many metropolitan authorities established to cope with sewage problems. The matter of special districts has been the subject of a recent book by a professor of political science.[3] This book is not entirely comforting to the sanitary engineer. The author states that special districts are justified for schools, but other activities should be returned to local governments. A sanitary engineer would conclude that special district governments are justified for sewage disposal as well as schools. In spite of this, the book is an illuminating treatise on the subject and anyone contemplating the formation of a metropolitan authority could probably learn many things from it.

Since 1950, six additional metropolitan areas have come into existence, and many more are in the making, and others growing ever larger. Not a single metropolitan area in the United States has one government operating throughout its area. The total number of separate local governments concerned with one or more angles of public service is 1,071 in the New York area and 960 in the Chicago area. In the 14 metropolitan areas containing 1,000,000 people or more, the average is 400 local governments for each metropolitan area. The multiplicity of governments existing in these metropolitan areas results in a complexity of service and control problems.

Other Metropolitan Growth Devices

While we may accept metropolitan districts as a proper approach, it is well to dwell momentarily on the other means which are available for accomplishing similar ends. Annexation is the first that usually receives consideration when fringe growth occurs. This is natural and normal in the community completely isolated from other metropolitan areas and state lines. The city grows in area, population and sometimes finds new problems. The 8 basic services — drainage, fire protection, garbage collection, police protection, sewerage, streets, water supply, and zoning — were *all* inadequate in areas annexed to more than one fourth of the cities reporting annexations. In addition the annexation procedure is generally laborious and complex, and results are often erratic and unpredictable.

Alternatives to annexation include consolidation such as city-county, variations of this combination, and city-county separation which is in effect in several locations. These consolidation moves have not met with general acceptance. This device has been used very rarely in recent years.

Other proposals to integrate city and county governments are sometimes known as metropolitan federations. Again, this has been proposed for several metropolitan areas in the United States but has not yet been put into operation. However, a number of city-county responsibilities have been shared by agreements between the two with some success.

Sanitary Districts

The first sanitary district was organized in Massachusetts as the Metropolitan District Commission giving sewage disposal service for the Boston Metropolitan Area. The second was the Chicago Sanitary District in 1889. Its name was changed to the Metropolitan Sanitary District of Greater Chicago in 1955. Now sanitary districts providing sewage disposal service are nationwide and the approximate number in existence is 451.

The State of Illinois was one of the first to see the value of municipal sanitary districts and its law authorizing their creation is dated 1917. The Chicago District was authorized as a special act of the Illinois Legislature. A complete study of these districts would be an education in both political science and sanitary engineering. Features and factors beyond the technical concern of the engineer include (1) representation of the area served and the mechanism for a democratic choice of such representatives, (2) a review of the authorities' activities by those served or their representatives from time to time to maintain the proper relation between the authority and those it serves, and (3) control of expenditures beyond those directly involved in or based on engineering considerations.

In a well detailed and informative paper on this subject[4] a general description of the sanitary district application is given. According to administrative functions these organizations are classed as (1) those which function as an arm of the state, (2) those which function as an arm of a municipal corporation, and (3) those which are created as new independent overlapping municipal corporations. The Boston and Chicago Commissions are characteristics of the first type, the Milwaukee Sewerage Commission is an organization of the second type, while most other sanitary districts fall in the third class. In general these incorporate the central city and the adjoining municipalities or unincorporated areas beyond the city limits.

A special class of organization is necessary where state lines are involved. The region of Kansas City, Missouri and Kansas City, Kansas is considering a bi-state sewer authority which will require approval of the legislatures of both states as well as the U. S. Congress. This is in line with general sanitary district developments, since the Kansas City's are essentially one city socially and economically and are in the same drainage area for sewage disposal. Another interstate example is the combined effort of Bristol, Virginia and Bristol, Tennessee. A contract between these cities has for its aim economy and effectivess in sewage disposal.

In the operation of sanitary districts the actual functions vary according to the local needs. In some instances, the sanitary district is the complete sewer system from the house connection to the point of discharge to a watercourse. This is truly the sewer authority. Many others leave in-town sewer problems to the city itself and provide interceptor, treatment and disposal service to member communities. The Joint Meeting sewer plan which originated and is used very successfully in New Jersey.

A uniform advantage of the sewer authority, sanitary district or sanitation commission is the placing of these essential sanitation services on a real utility basis. The most frequent meth- of of financing these organizations is through sewer service charges. The use of sewer service charges both inside and outside of sanitary authorities has proved their value in meeting the needs of the public. It is interesting to note that the Illinois law denies the power of service charges, and provides for income from property tax. Many of the more recently authorized organizations are financed on sewer

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service charges and some originally financed on a property tax basis have been authorized to base charges on service.

Role of Engineer

It would first appear that the engineer's principal interest in metropolitan problems would lie in the design and extension of systems to serve a growing metropolitan area. Actually, there is much that an engineer should do before this time and certainly one of the great challenges is his early interest and activity in (1) citing the needs for state legislation or changes in it which would enable metropolitan areas to provide essential sanitary services based on long range decisions rather than those of expediency at times of great urgency; (2) helping in the actual drafting of legislation or changes therein which will pave the way for future progress; and, (3) watching developments and pointing out deviations from proved practice.

A challenge comes to the engineer when he has the task of organizing a group of communities for the mutual protection and economy of sewer service. The public relations aspect of such work can not be overlooked. The engineer can help inform the public and share factual data by reducing it to the most understandable terms.

The phase of preliminary estimates is likewise one of great importance. Costs estimates should be made with the greatest care so that upsetting increases will not have to be authorized as the project takes form. In a period of inflation, cost estimates should be labelled as to date so that they can be re-evaluated if necessary. The engineer must make decisions solely for the benefit of the area and must provide facilities for a sufficient period in the future to avoid the embarrassment and expense of early obsolescence. He must prepare plans and specifications that will fulfill future needs and be accomplished at a reasonable cost.

Upon completion of the works, it would appear that engineering work is much reduced, but it simply changes form. The operation of the project requires full skills in sanitary techniques. The operational responsibility and the administration and management of the authority are largely an engineering activity. Laboratory results on the plants and receiving waters must be evaluated to determine the accomplishments of the project. This information is necessary to justify additional improvements or system extensions. This information should be publicized sufficiently to show the authority's accomplishments and their costs.

Certainly a tremendous challenge to engineers engaged in metropolitan planning work is (1) the long range planning of metropolitan areas and (2) the enforcement of planning laws and regulations to make them of full effect and value. In addition to planning and zoning engineering, health departments are usually required to certify as to the satisfaction of water and sewer facilities. Such regulation is all for the benefit of sound metropolitan growth and development. Real estate developers are generally more eager to pipe public water supplies to their homes under construction than to provide community sewer service. This is a natural reaction, because all but the larger builders are attracted to unit by unit operation from the standpoint of financing and sales.

Aerobic Treatment Devices

Sewer services in fringe areas can become unreasonable due to the cost of sewer extensions. This has caused many developers to turn to individual household sewage treatment rather than providing a community sewer system. Although the septic tank has been in traditional use, this unit now finds itself in competition with more complicated devices which I choose to call aerobic individual household sewage treatment plants. These are being offered by reputable firms.

The development of individual household units may find application in areas where subsurface effluent disposal is out of the question or where the effluent may be discharged to a storm sewer. It is not considered entirely safe to permit the discharge of these plant effluents on the surface of the ground or small watercourses accessible to persons. The availability of a storm sewer is unlikely in an area that has not yet provided itself with sanitary sewers, but effluent discharge into a storm sewer system is a definite possibility.

Perhaps the greatest value of the aerobic plant development is in the construction of package plants for community use. With these, a small community may comply with its sewage treatment requirements and at the same time avoid the limitations of neighborhood nuisance, which septic tank effluent disposal may cause. A community benefits by having the street sewers laid early in the project development, thus avoiding costly conversion from septic tank to street sewer service. Construction of a common sewer in a street that has been paved costs three times what it would have originally.

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Sewage Works in the United States

by JOHN R. THOMAN and K. H. JENKINS

Water Supply and Water Pollution Control Program, Division of Sanitary Engineering Services, U.S. PHS, Washington, D. C.

This summary is based on data contained in the U. S. PHS 1957 Inventory of Municipal and Industrial Waste Facilities, although the 1953 data are the latest available from Alabama, Louisiana and Michigan. It contains only data on municipal wastes and does not include industrial wastes.

The basic tabular data in the complete report are presented in three major classifications: Population groups (eight from under-500 to more-than-100,000 population), States, and drainage basins (fifteen). The data show considerable progress in combatting stream pollution by municipalities, but in spite of these gains there has been a small increase in total pollution load on streams.

Statistical Summary of Sewage Works in the United States

Data on Communities and Facilities

	1940	1945	1949	1957
Sewered Communities				
Number	8,516	8,917	.....	11,131
Population—millions	75.7	82.0	.....	102
Connected	70.5	74.7	78.9	98.4
% Connected	93.1	91.1	.....	96.4
Sewered Communities without treatment				
Number	3,597	3,610	3,718	3,165
Population—millions	29.9	27.9	28.1	21.9
Severed Communities with treatment				
Number	5,085	5,480	6,816	8,066
Population—millions	40.6	46.9	50.8	76.4
% of total sewered pop.	57.6	62.1	64.4	77.7
Type of Treatment Facilities—No. of plants				
Minor	49	60	54	41
Primary	2,889	2,829	3,019	2,730
Intermediate	2,630	98	107	100
Secondary		2,799	3,050	4,647
Total	5,580	5,786	6,230	7,518
Population served by type of treatment facility—millions				
Minor	3.3	4.3	3.9	1.8
Primary	15.1	17.2	17.2	25.7
Intermediate	22.2	3.8	3.6	5.6
Secondary		21.7	26.1	43.3
Total	40.6	47.0	50.8	76.4
Population served by type of treatment facility—millions				
Activated sludge	10.5	11.6	.....	25.0
Chemical treatment	4.0	5.3	.....	7.3
Intermittent sand filters	0.9	1.0	.....	0.9
Lagoons	.....	0.2	.....	2.4
Land application	0.9	1.3	.....	2.0
Trickling filter — std.	8.4	8.8	.....	11.3
Trickling filter—high rate		0.7	.....	6.5

Breakdown of Plant Facilities—1957

	No. of Plants	Est. Pop. Served	% of Est. Pop. Served
Primary treatment			
Septic tanks	780	1.0	3.8
Imhoff tanks	1,084	3.3	13.0
Mech. cleaned tanks	656	18.6	72.7
Plain hopper bottoms	80	1.3	5.2
Others	130	1.3	5.3
Total	2,730	25.5	100.
Secondary treatment			
Activated Sludge			
Mech. Aeration	259	0.9	2.1
Diffused air	284	20.2	46.5
Other	46	3.7	8.5
Trickling filters			
Standard rate	1,870	9.3	21.6
High rate	812	6.0	13.8
Sand filters	394	0.8	1.9
Land application	340	1.0	2.3
Oxidation ponds	430	0.8	1.8
Other	212	0.7	1.5
Total secondary treatment	4,647	434	100.
Chlorination	2,216	37.8	—
Grit removal	1,581	51.7	—
Sludge processing			
Septic tanks	1,120	.....	—
Inhoff tanks	2,759	.....	—
Stage digestion	272	.....	—
Separate digestion	2,790	.....	—
Drying beds	5,342	.....	—
Lagoons	167	.....	—
Mech. dewatering	197	.....	—
Miscellaneous	2,007	.....	—

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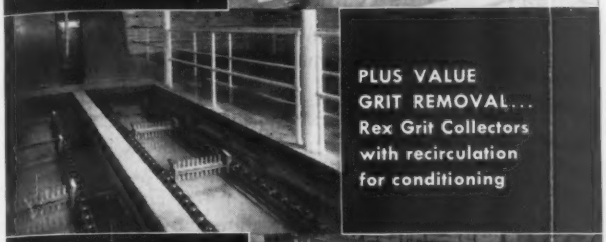

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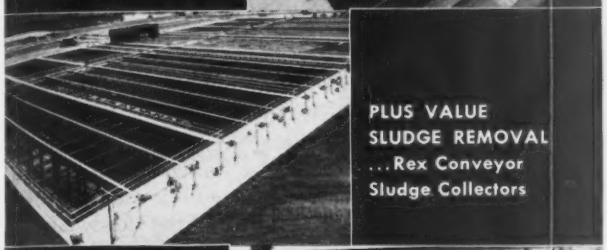

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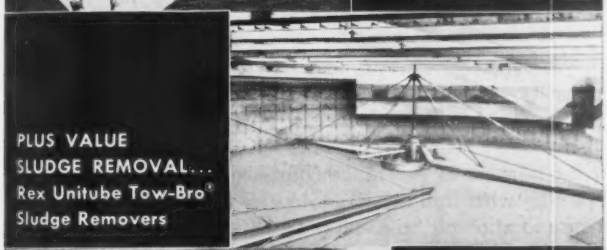

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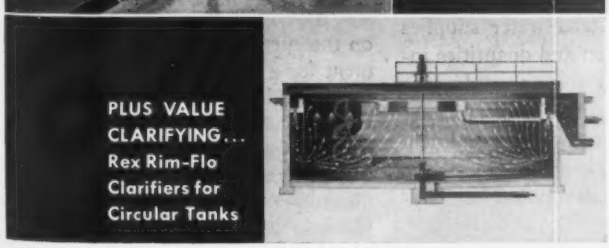

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OBSERVATIONS ON VITAL DATA FOR STREAMS*

By EDWARD J. CLEARY

Executive Director and Chief Engineer, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio

Assembly and interpretation of data relating to water pollution control have not been distinguishing attributes of sanitary-engineer administrators. This deficiency and the means for remedying it deserve exploration.

In so doing it might be recalled that the President's Advisory Committee on Water Resources Policy felt compelled to remind engineers and administrators that too often they did not know what they were talking about. Of course, the manner of stating it was somewhat more elegant. But the meaning was plain. The committee said that until there were adequate basic data on water resources the opportunities for developing sound policies and programs would be greatly hampered.

It seems a little odd, however, that neither in the President's Advisory Committee report—nor elsewhere for that matter—has the importance of such activity been reflected by the choice of terminology more dynamic and meaningful than the assembly of "basic" data. The data that is lacking actually is "vital" information. Why not, therefore, tag it in a manner to connote its significance?

In saying this there is some awareness that legislators who pass on budgets may be more responsive to providing funds for "vital information" than they might be to an item that bears the prosaic title of "basic-data assembly."

But at this point a question is necessary: How many state and interstate pollution control agencies would agree that basic data are vital to the conduct of their programs? Perhaps not too many, if the record of past performance is any guide.

What Constitutes Vital Data?

It is suggested that there are at least two areas of discussion that merit exploration—What constitutes vital data; and, why are vital data needed?

In regard to what constitutes vital data, the needs of the water pollution-control administrator in these categories are summarized as follows:

Inventories

These would include, as a minimum, a tabulation of those communities and industries discharging waste into a stream, with details on the status of control facilities for each. Such an inventory would be revised once a year. Ideally, this inventory might include financial and design data; but it could be argued that this additional information is not essential for an appraisal of the status of the various states in pollution control from year to year.

Industrial waste load to streams

The second major category of vital information is one that would provide a record of industrial waste loads that are discharged directly into a stream. This record is for the purpose of establishing who is putting what into a stream and the precise location of the discharge. Provision should be made to revise this record in accordance with changes that occur in existing discharges and the addition of new sources of discharge.

Water Use

A third category of vital information is a catalog of water use. This invites not only the inclusion of municipal and industrial water supplies in terms of location and quantities involved, but likewise should give cognizance to all other uses. Among the latter, of course, are agricultural services, recreational and esthetic pursuits, fishing, navigation, and hydropower.

Quantity and quality aspects of streams

The final category is one that embraces vital information on the quantity and quality aspects of streams. This includes hydrologic information with particular reference to determination of minimum-flow characteristics. And it claims consideration of collection, analysis, and evaluation of data relating to quality conditions and their variation in a stream.

Why are the Data Needed?

Among administrators there is divided opinion as to the need for vital data.

A few will question why it is necessary to belabor the point since it is obvious that these data are needed.

By far the majority in this audience reflects the following viewpoint: "This is all very nice, but already there are so many burdens that there is no time to develop such records." To these the following response is given: An administrator is doing himself and his program an injustice to look upon this activity as something that might be done only when and if time permits; this attitude is self-defeating. Quite frankly, these officials are already sacrificing large blocks of their time, energy, and peace of mind because of the lack of adequate records.

Administrative Examples

Just a few months ago, the chief engineer of a state health department complained rather bitterly that the demands on his time had just about reached the breaking point. And then he cited this experience: His governor called on a Friday afternoon and asked for a summary statement on the current status of sewage treatment for a speech he was to make on the following Monday. To meet the request the chief engineer said he had to spend all of Saturday and most of Sunday culling through department files to get some information together. He was mightly unhappy over what

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he called "the unfortunate timing" of the governor's request. It is suggested that the real cause of his discomfiture might have been the lack of a record system whereby information could have been brought together in a matter of minutes by one of his assistants.

Recently this incident occurred in another state. The administrator and a part of his staff had been submerged for several weeks in the task of meeting a request from a committee of the legislature. What was the request? It was the preparation of a tabulation showing the number of new pollution-control facilities that had been built each year over the past five years!

These are not extraordinary instances of an individual or an agency being strained in order to meet requests for facts about a program. What is extraordinary is the state of mind that permits the inevitable to happen over and over again without doing something about it.

There are reasons to believe that pollution-control agencies apparently do not enoy the public confidence that their efforts would seem to justify. What is the reason? Could it be that the agencies are seldom sufficiently armed with facts when issues are presented for appraisal?

As further evidence the remarks of a gentleman who represents a potent and articulate segment of conservation-minded individuals are pertinent. He indicated that a majority of his group had reached the conclusion that the time had passed for water pollution-control to be entrusted to what he described as "uninformed and uninspired apologists wearing the badge of sanitary engineers." He then went on to say that the record—or lack of it—showed very little evidence of accomplishment, despite years of alleged effort.

These remarks came as a shock. But upon later reflection it was conceded that here may have been a point—at least so far as the evidence from records was concerned. For example, the mass of testimony presented at the hearings on Public Law 660 is not very consoling on this score—certainly one can learn very little about the positive accomplishments in pollution control. Yet, there is reason to believe that in at least two states more than 92 per cent of the sewered population is served by treatment facilities. And it is speculated that equally significant accomplishment could be cited for other areas if the facts were compiled.

Therefore, this question is asked: Is it fair to an administrator, to the program he administers, and to the public that he so diligently serves, not to have the basic facts to aid in a realistic appraisal of the situation?

This plea, however, is not that there be collection and analysis of facts simply to be armed for purposes of pointing with pride or for viewing with alarm. More importantly, it is asserted that officials are handicapped professionally when they deprive themselves of information essential to engineering and economic decisions relating to pollution control.

Industrial Wastes

A case in point is the situation with regard to industrial waste discharges. With few exceptions, control agencies have not been distinguished in keeping abreast of who is discharging what into the streams. Yet, more than half of the states operate under laws that make it mandatory for industries to report such information. This, then, is the question: Can administrators carry on an aggressive and professionally competent program of control without compiling and using such vital information? A positive reply to this is doubtful. There are cited the numerous special investigations and surveys that must be inaugurated every time a problem condition develops in a stream.

It might be asked if some of these problems could not be anticipated and remedial measures instituted through the operation of a proper system of records and their evaluation. At least, much time-consuming and otherwise expensive work might be minimized.

On this matter of administrative practice with regard to industrial-waste discharges, some recent findings are of interest. They are based on information supplied in response to a recent questionnaire. These findings are briefly summarized.

Thirty-seven of the states operate under legislation requiring an industry to secure a permit of approval of plans prior to discharge of wastes into a stream. But it appears that only half of the industries that are required to have a permit are presently meeting this obligation. And in only three states is it a requisite for an industry to apply annually for review and reissue of a permit. Only 16 states are interested in the quantity and characteristics of the effluents discharged from industrial plants to the extent that they require a monthly report; four states are satisfied with a yearly report.

Do not these findings suggest there may be some validity to the charges by conservation groups and others that administration of industrial wastes control can be characterized as something less than positive?

A simple yet effective performance-rating system for industrial wastes control has been described by Adams[1]. By this method all concerned—the agency, the industry, and the public—are kept abreast of activities in the control of industrial wastes.

Federal Agency Activity

It is to be hoped that the emphasis now being placed on data assembly by the Public Health Service will make it possible to publish the inventory of sewage disposal facilities more frequently than in the past.

There is both a professional and public need for such information. During the hearings on the Water Pollution Control Act, for example, the enlightenment of up-to-date facts would have been most helpful. And now that the federal-aid construction program is under way the desirability of having a proper baseline from which to draw comparisons in the future is even more pressing.

With regard to the Public Health Service program being established to secure stream quality information from a network of stations throughout the nation, this likewise can be viewed as of great significance. Experience in the Ohio Valley during the past seven years with a quality-monitor program provides some basis for saying that this is not a glamorous task. But the dividends from diligence in this work provide rewards beyond measure.

In fact, all aspects of vital-data assembly and interpretation promise rich rewards. And these remarks have been designed to inspire further activity toward realization of these rewards.

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Streams and Sewage Treatment

by DON E. BLOODGOOD

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A LARGE percentage of the water used by municipalities in the United States is obtained from surface supplies. It is necessary to control in these surface waters the concentration of constituents that make it impossible to prepare a safe and economical finished water. A considerable amount of organic debris does enter streams, and must undergo decomposition if it is not to accumulate in prohibitive amounts. This discussion will review the factors affecting decomposition, as well as the importance of maintaining streams of high quality.

Natural Purification in Streams

The decomposition that takes place when organic matter is discharged into surface water is sometimes considered to be unnatural. In reality, decomposition is a normal method used by nature to reduce the concentration of solids remaining in water.

If decomposition in streams is a natural procedure, it may well be asked, "Why not let nature carry on in her own way?" This would be the very thing to do if decomposition could take place without harming or offending human beings.

The public health is endangered when discharged organic wastes contain pathogenic bacteria. Organisms that live on or in the warm-blooded animals may be harmful to others of the same group. It is also known that few of the pathogens (disease producers) multiply in streams or lakes. Phelps[1] has reported that there is a rapid decrease in the disease organisms once they are discharged into surface waters. Table 1 shows the decrease in numbers of organisms with time.

The environment in a stream is not ideal for the growth of the disease-causing organisms. The decrease in bacterial numbers with time indicates natural purification of the water. It is not safe or advisable to depend upon natural purification, however, because during the period prior to death of the last pathogen some person may consume the water. If the water has not been made safe by treatment, the health of the user will be endangered.

There is more involved in the natural purification of streams than the death of bacteria. Streams receiving sewage will contain organic solids as well as bacteria. It has been previously pointed out in the preceding series that the decomposition of organic matter in streams may cause a nuisance. This will occur if the available oxygen is not adequate to meet the needs of a growth of bacteria sufficiently large to consume the organic solids. When the concentration of solids in the water is *less* than that amount needed to support a growth of bacteria which will use the oxygen in the water faster than it can be replaced from the atmosphere, then there will be dissolved oxygen remaining in the water.

TABLE 1

Death Rate of E. *Coli* in the Ohio River

Warm Weather		Cool Weather	
Days	% Dying	Days	% Dying
0	100	0	100
2	90	2	85
4	99	4	95
6	99.5	6	97
8	99.2	8	98

Reaeration in Streams

According to Phelps[1], Stearns stated in 1890 that stream flows of less than 2.5 c.f.s. per thousand sewered population was insufficient to prevent offensive conditions, and that a stream flow of 7 c.f.s. would practically guarantee a satisfactory dilution.

Seven cubic feet per second is 37.7 million pounds per day (7.0 c.f.s. $\times$ 60 sec./min $\times$ 1440 min/day $\times$ 7.5 gal./c.f. $\times$ 8.33 lb./gal. $\div$ 1,000,000). The B.O.D. per capita is .167 pounds or 167 pounds for one thousand persons. The solubility of oxygen in fresh water 9.2 ppm. at 68° F. In 37.7 million pounds of water there would be (37.7 $\times$ 9.2) 347 pounds of oxygen. If there were no reaeration of the stream (and there always is), 167 pounds of oxygen would be used and (347 — 167) 180 pounds would remain in the water. The dissolved oxygen content would be (180 $\div$ 37.7) = 4.8 ppm.

Aeration of the water in the stream takes place quite rapidly, particularly if the oxygen content of the water is considerably below the saturation point. Exposing a water surface to the air permits oxygen to enter the water very readily. It may be useful to think of the oxygen molecules as bullets flying around freely in the air. When they hit a water that is not saturated with oxygen they are not readily returned to the atmosphere. However, when the water becomes saturated, the rate of oxygen returning to the air is equal to the rate of oxygen entering the water.

Oxygen Concentration Variation

Turbulent water such as that flowing over rough stream beds, over dams, and in very shallow streams,

readily picks up oxygen. In many instances where oxygen is being consumed by bacteria in oxidizing organic matter, the oxygen is being replaced from the air at a rate that maintains the dissolved oxygen at or near the saturation point.

If the oxygen cannot be supplied to the stream as rapidly as it is being used, the oxygen soon disappears and the body of water is then said to be septic. Once a body of water has become septic the decomposition of organic matter does not stop, but rather a different type of decomposition takes place in which the oxygen is obtained from the organic constituents. Septic action is termed anaerobic decomposition. Anaerobic decomposition is usually taking place in the sludge banks that form in streams which receive organic polluting materials.

The quantity of oxygen that can be held in the water of a stream depends upon the temperature of the water. The salt content of water is also a factor that determines the concentration of dissolved oxygen. Table II shows that the higher the temperature the lower the concentration of oxygen required for saturation, and the higher the salt concentration the lower the saturation point[2].

The Stream Flow Factor

The Stearns figures on the rate of flow of a receiving stream and the quantity of sewage discharged certainly indicate that rate of flow is very important in determining the intensity of pollution. The amount of dissolved oxygen present in water is an indication of the severity of the pollution. Table III gives data collected on White River below Indianapolis some years ago[3]. It shows that the dissolved oxygen was as high as 11.8 ppm when the flow in the stream was 1471 c.f.s., and that it was as low as 0.3 ppm when the flow was 324 c.f.s. Table III shows that rate of flow has an effect on the dissolved oxygen. There are other factors, such as temperature and B.O.D. load, that must also be taken into account if an exact mathematical relationship between stream flow and dissolved oxygen is to be established.

TABLE II
Saturation of Water With Oxygen

Temp. °F.	D.O. ppm	D.O. ppm 2000 ppm chlorides
32	14.6	11.3
41	12.8	10.0
50	11.3	9.0
59	10.2	8.1
68	9.2	7.4
77	8.4	6.7

TABLE III
Stream Flow and Dissolved Oxygen
White River, Below Indianapolis, Ind.

Month 1933	Temp. °C.	D.O. ppm	Thousands of Lb. BOD/Day	Flow in River c.f.s.
January	7	10.5	36.0	3337
February	1	11.8	35.4	1471
March	7	9.1	31.6	4494
April	12	8.8	41.3	3559
May	18	7.2	53.3	.7494
June	26	2.8	55.1	1036
July	26	0.2	40.8	436
August	26	0.5	46.2	436
September	25	0.7	46.4	641
October	17	2.3	31.4	454
November	13	0.3	42.8	324
December	9	1.0	36.4	415

Temperature Factor in Streams

An elevated temperature, in addition to decreasing the amount of oxygen in water, also increases the activity of microorganisms that are decomposing organic matter. The result is that oxygen is used more rapidly in the summer than in the winter. Table IV illustrates the relative rate of decomposition at several temperatures[4]. The figures in the table show that the rate of decomposition at 62° F. is twice as fast as it is at 35° F.

Stream Quality and Plant Operation

The preceeding discussion shows the effect of temperature and stream flow on the apparent condition of the stream. Perhaps comment on the importance of temperature and stream flow to sewage plant operation is in order.

Babbitt[5] reports that the removal of B.O.D. in primary sedimentation treatment plants to be 37 per cent.

In considering primary treatment only (and there are many plants that provide only primary treatment) it is reasonable to believe that this degree of treatment usually does remove enough B.O.D. in the summer when the stream temperature is 70° F. or more. From Table IV it can be seen that the activity in the stream would be much less at a lower temperature. In fact, if primary sedimentation removed 37 per cent of the B.O.D. during the warmer period, the stream might be expected to have about the same dissolved oxygen content as if primary units were by-passed during the time the stream was at a temperature of about 55°. It is true that the solids settled out in the stream might form sludge banks. The importance of considering the temperature factor before deciding when to make repairs to a sewage plant can readily be seen.

Streams and Public Health

Sewage-contaminated water can be so treated that the resulting product is suitable for human consumption. In purifying a contaminated supply, however, there always is the likelihood that some day some pollution may get through the water treatment plant without adequate purification. The chances of producing a safe product therefore, are much better if the raw water supply contains relatively few pathogenic bacteria.

The bacteria are removed from sewage in various treatment processes. Some bacteria are attached to solids and are removed when the solids settle out. Single bacterial cells are probably coagulated into clumps in the activated sludge and trickling filter processes. Chemical coagulation, no doubt, helps in the removal of some bacteria. Care must be taken to see that the bacteria are destroyed after removal from the sewage with sludge solids. Most disease organisms die in the foreign environment of the sew-

TABLE IV
Temperature and Rate of Decomposition of Organic Matter in Streams

°F.	Relative Rate of Decomposition	°F.	Relative Rate of Decomposition
35	1.000	60	1.892
40	1.137	62	2.000
45	1.292	65	2.155
50	1.468	70	2.450
55	1.666	75	2.790

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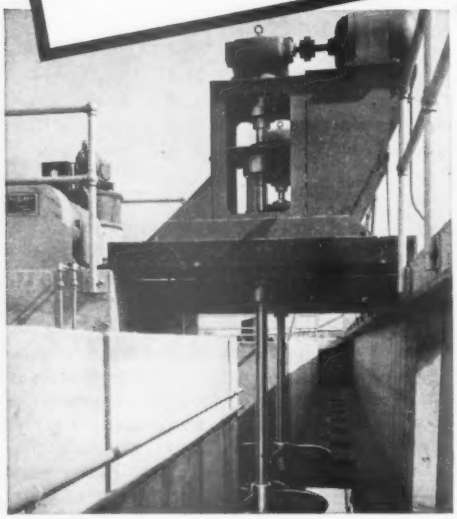

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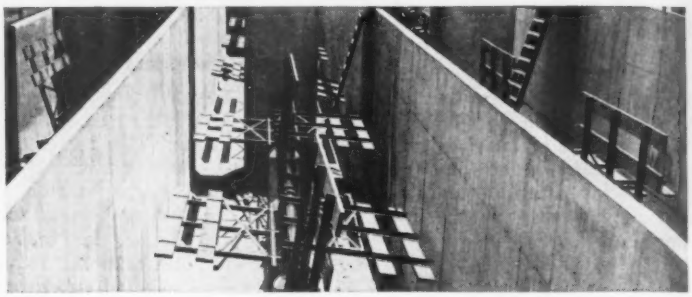

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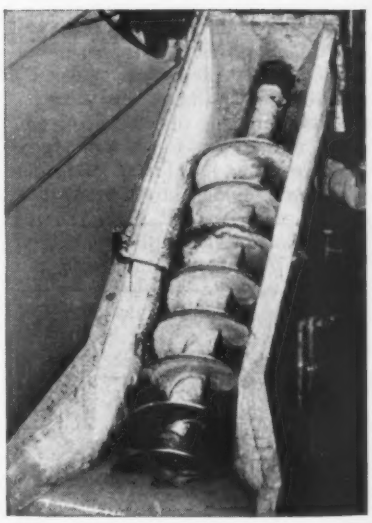

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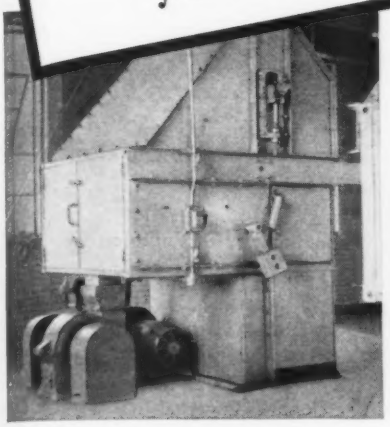

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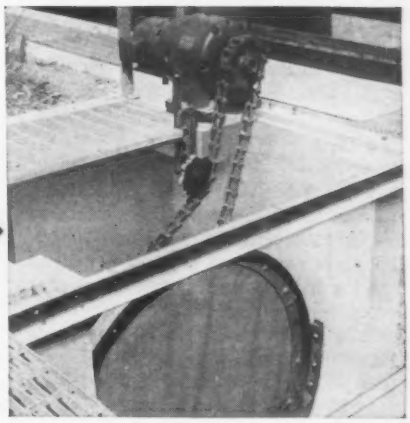

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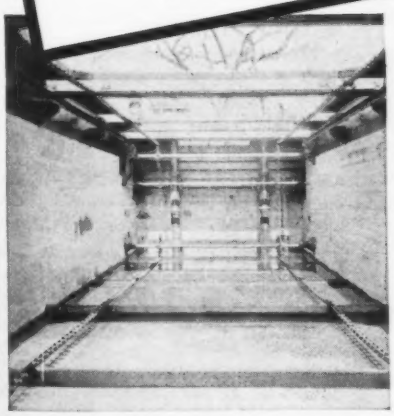

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age plant (the digestion tanks, etc.), however, it is not possible to be sure that all dangerous organisms are destroyed unless the sludge solids are heated to a temperature sufficient to kill bacteria.

Streams and Fish Life

The number of pounds of fish that can be grown per year in a given volume of water depends upon the food supply available, and how satisfactory the environment is. It has been pointed out that the decomposition of organic matter in streams is accomplished largely by microorganisms. The mocroorganisms become food for the larger forms of life and eventually fish use either plants or crustacea for food.

If decomposition has altered the environment by lowering the dissolved oxygen to a point where there is not enough remaining to support fish life, then the fish will die. However, if the decrease in oxygen is not enough to harm the fish, then the fish should appear in greater numbers or size because of the increase in food that is available from organic matter.

Katz and Gaufin[6] have reported that they found pollution may be detrimental to fish even when the dissolved oxygen concentration is adequate. They believe that the pollution is not directly responsible for fewer numbers of fish in water with ample oxygen, and they are of the opinion that pollution so changes the flora in the stream that there may not be suitable food in certain parts of the stream for the fish.

Southgate[7] has reported that rainbow trout are killed in a short period at an oxygen concentration of 2.0 ppm at temperatures between 15 to 17° C. Trout are the most sensitive of all fish to oxygen deficiencies. Extensive studies have been carried on in recent years by the National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries) on the effect of oxygen concentration on various fish. The Aquatic Life Advisory Committee of the Ohio River Valley Water Sanitation Commission has said that well-rounded warm water fish populations require at least 3 ppm of oxygen at all times, and that for sixteen hours per day the water should contain not less than 5 ppm.

Algae Growth in Streams

Algae, like other plants, grow best when fertilized. A stream that receives nitrogenous materials soon turns them into plant food. Thus, the natural purification that takes place in a stream provides food for algae. Algae are plants which give off oxygen in the sunlight and use some oxygen in the dark. The exact effect of algae on the stream condition is not easily predicted, because of fluctuations in numbers of algal cells and the hours of sunlight that can be expected.

The algae can, in bright sunshine, produce and give off enough oxygen to super-saturate the water. A very good idea of the variation in dissolved oxygen in water that may be expected in a day at one particular point is given by the data presented in Table V.

TABLE V
Variation in Dissolved Oxygen Over 24-Hour Period
Clearwater Lake, Waconia, Minn.

Time Hour	Dissolved Oxygen, ppm	Time Hour	Dissolved Oxygen, ppm	Time Hour	Dissolved Oxygen, ppm
10 A.M.	3.1	6 P.M.	10.5	2 A.M.	6.5
11	3.9	7	10.3	3	5.3
12 Noon	4.5	8	11.6	4	4.6
1 P.M.	5.2	9	11.1	5	3.7
2	6.6	10	9.8	6	2.1
3	5.1	11	9.2	7	3.0
4	5.1	12 Mid.	11.3	8	2.7
5	9.3	1 A.M.	7.6	9	1.6

The data given in Table V illustrate two things: (1) algae can add large amounts of oxygen to a stream, and (2) it makes a great difference at what time of day a sample is taken to determine the dissolved oxygen[8]. Certainly these data show that the seriousness of the pollution in this lake could not be determined by taking a sample in the afternoon. The indications are that algae usually will produce more oxygen in the daytime, by the process known as photosynthesis, than they will use up in the darker hours by respiration.

Sludge Banks in Streams

Sludge banks are formed in streams when the settleable solids in the water are deposited at locations where the velocity of the water is low enough to permit deposition. Sewage or industrial wastes not treated by primary sedimentation are sure to produce sludge banks unless the stream is flowing with a high velocity. Dissolved and colloidal solids also may form sludge banks in streams if these materials are transferred into settleable solids by microorganisms. Therefore, treatment in addition to primary sedimentation may be necessary in order to prevent the formation of sludge banks.

Requirements for Pollution Control

If pollution control is to be enforced for the preservation of stream quality, then the regulations should indicate the condition of the stream that must be maintained rather than the quality of water that can be discharged into the stream. It seems essential also that all pollution control laws should in some way limit the discharge of settleable solids, bacteria, dissolved organic matter and those substances that are considered to be toxic.

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Sewer Use Regulations

by municipal ordinance

by DON E. BLOODGOOD

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Many laws and regulations are required to keep our organized society functioning as it is intended. There are common, federal, interstate and state laws that guide the cities of the United States in carrying on their activities. In the local communities there are ordinances that dictate what is best for the greatest number of people. These local regulations are very real to the people who are living under them. Consequently, the local administrations are vitally interested in the regulations and in many cases are called upon by the legislative group to help in the tentative formulation of the legal controls.

Of the many phases of local government the one dealing with sewage disposal is considered to be very important. The regulations governing the planning, financing, and construction are all very important. A fourth group of regulations, the ones that control the use of sewage disposal facilities, are also very important. In fact, this phase of regulation is neglected in some communities. The introductory paragraph to the Manual of Practice No. 3, Municipal Sewer Ordinances, of the Federation of Sewage and Industrial Wastes Associations[1] says, "Of all public utilities, sewage collection systems are probably most abused through misuse. This situation has come about because of (1) a common misbelief that a sewer can carry away any unwanted substance or object that can be put into it, (2) the lack of adequate regulations setting forth the proper uses and limitations of the system, and (3) the lack of complete enforcement by municipal authorities of existing regulations."

These same statements apply to the use of sewage disposal facilities. In recent years many new ordinances have been written but there are still many cities with no regulations or very antiquated regulations for the protection of the sewers and sewage disposal plants. Sewers and sewage disposal plants exist for the purpose of disposing of unwanted materials in a community, therefore, it is necessary for those who direct the preparation of legal controls to keep this fact in mind.

The classes of materials that are disposed of in sewers and treated in sewage treatment plants are domestic sewage, garbage and industrial wastes. Under certain conditions it may be possible to dispose of all three by the same sewers and sewage treatment process, while in another situation it may be advisable to regulate against such a procedure.

Distribution of Costs

In any event, there should be a suitable arrangement to have the costs of collection and disposal distributed equitably. The lack of such an arrangement has been a deterrent in some instances to the combined treatment of all three classes of wastes. The distribution of costs is done in many ways; one of the best guides in the selection of a method is Bulletin No. 7, "Sewer Rentals," by the American Public Works Association.[2] They also have published Special Report No. 18-S, "Industrial Waste Disposal Charges in Cities Over 5,000 Population"[3] and Special Report No. 18 "Sewage Service Charges in Cities Over 5,000 Population."[4]

If the sources of wastes are in existence prior to the construction of collection and disposal facilities, costs should not be a reason for excluding any wastes unless they can be shown to be a hindrance to the proper collection and treatment of any one of the waste classifications.

Importance of Bacteria

The municipal sewage treatment plant is built for the purpose of protecting the public health by disposing of the human wastes that contain pathogenic bacteria that may be present. The domestic wastes also contain organic matter that can be decomposed by natural bacterial flora that find the organic materials in sewage suitable for food. This process of decomposition of orangic matter by bacteria is nature's way of keeping the world in chemical balance. The modern sewage treatment processes for domestic waste disposal are the natural processes harnessed to do the required work in a confined area or volume.

It is known that certain bacteria can and do purify domestic wastes and in a more satisfactory and economical way than by any other means presently known. Therefore, if the activated sludge, trickling filter or sludge digestion processes are to be used it is necessary to prohibit the discharge of any substance that will be detrimental to the bacteria being relied upon to do the purification. Such a requirement, if written into an ordinance, could be, if literally taken, a law prohibiting the admission of minute quantities of any substance into the sewer system. For practical reasons this cannot be the case and it then is necessary to determine equitable controls on the wastes discharged.

Wisely[5] has said, "There is certainly no question but that many problems of sewage treatment can be eliminated or partially solved by the proper regulation of the usage of the sewage

collection system. Without proper control, a public sewer system cannot render completely satisfactory service; it becomes a hazard to the public safety and entails a substantial waste of funds used for original and corrective construction."

One Plant Treatment

It has been stated that it is more economical to treat a quantity of waste in one plant than it is to do the same work in two separate plants. This is true if the materials to be handled are all compatible in a treatment process. By this philosophy it would be possible for municipal sewage treatment plants to take care of all industrial wastes. As is well known, this has not been the policy for the years gone by. There must be some reasons then why municipal sewage treatment plants do not take all industrial wastes and treat them along with the domestic sewage.

Difficulty in Writing Regulations

It is most difficult to write regulations on the discharges of industrial wastes to sewer systems because of the variation in conditions that may exist. As an illustration, when pickling liquor containing ferrous sulfate and sulphuric acid is discharged as a waste material into a concrete sewer without dilution the waste will destroy the concrete; if however, the pickling liquor is discharged into a sewer that has a considerable flow of sewage with considerable natural alkalinity the acid will be neutralized and the iron precipitated. In some activated sludge plants the iron oxide actually appears to be an aid to the process. In one municipal plant in Indiana the pickling liquor does not injure the sewers but the iron does coat the air diffusion tubes in the aeration tanks and causes some clogging. It appears, then, that it is quite difficult to set down hard and fast regulations regarding the discharge of some materials into municipal sewers.

There are some materials that are discharged to sewers that could be much more easily disposed of if they were not mixed with sewage.

Inert Solids

Such materials as sand, ashes and cinders can be taken out of sewage in the grit chambers of a sewage plant but when they are a mixture of organic and inorganic materials and it may, therefore, be difficult to dispose of them. Sand and other heavy inert materials may settle out in sewers and cause stoppages. There is a record of a sewer stoppage with ground glass that came from a washing plant processing broken bottles. It would sound peculiar in some communities to have a statement in an ordinance that said no broken glass shall be discharged to the sewers. If for some reason a foundry wished to dispose of its waste sand from a reprocessing plant by discharging it to the sewers, it could be removed by the grit chambers if it could be transported to the sewage plant. The sand removed at the sewage plant would not be as satisfactory for fill as it would have been if it had been removed directly from the foundry.

Oils and Solvents

The discharge of gasoline and other volatile, combustible solvents cannot be tolerated in a sewer system or a sewage treatment plant. The explosive solvents are dangerous in sewers and in pumping stations and it takes very little of them to cause serious trouble. Oils, whether light or heavy when received at the plant in the sewage, are not decomposable in the biological treatment plants. The lubricating oils may coat the sewage solids with films that cannot be penetrated by the oxygen that must get to the bacteria if they are to decompose the organic matter. Small quantities of oils discharged daily may accumulate in the digestion tanks of a city sewage plant, particularly is this true if the skimmings from the primary settling tanks are pumped to the sludge digestion tanks. The oils interfere with the biological processes and should, therefore, never get into the sewer.

It is not practical to rule that it is a criminal offense to add a thimble full of oil to a sewer, but certainly any filling station that discharges waste crankcase oil to the sewer should be required to take steps to prevent such a discharge, even though the discharge might amount to only a few parts per million in the total sewage flow.

Feathers and Hair

Feathers in sewage are very troublesome and they can cause a tickling filter to be ineffective because of the constant clogging of the filter nozzles. Feathers in a poultry packing plant can be quite easily collected so it seems only reasonable that they be excluded from sewers and sewage plants.

Hair from tanneries or meat packing plants can be removed by sedimentation but the hair in the sludge is not readily digested. It has been known to collect as a sludge mat on the top of a digestion tank, thus interfering with gas release. In these days of sludge recirculation it may be possible to keep the hair in suspension and move it on out of the tank with the digested sludge. It does not seem reasonable to require a sewage treatment plant to remove hair in large quantities.

Garbage

There are some communities that have written ordinances prohibiting the discharge of ground garbage to the sewer system. Such regulations do not seem to be reasonable in many ways. The collection and disposal of garbage like the collection and disposal of sewage, is usually a municipal responsibility. Garbage is organic matter of much the same chemical nature as sewage solids, therefore, it decomposes in much the same manner as do sewage solids. The garbage, when properly ground will be of a size that will classify it as primary sludge. It can be pumped without trouble as primary sludge and it will digest with sludge, producing gas of approximately the same quality as sewage gas. If the garbage is ground in the homes any grit-like material will be removed in the sewage plant grit chambers so that there will be no great accumulation of grit-like materials in the bottom of the digestion tanks. It has been shown by the experience at Jasper, Indiana, that ground garbage causes no trouble in the sewer system. One often hears the statement that garbage will overload the sewage plant. This may be true but it seems only logical to say that an enlarged sewage plant can be built and operated to handle ground garbage without detriment to the functioning of the sewage treatment plant. There really seems to be no good reason to exclude garbage that has been ground in homes.

Water Softening Sludge

Some cities have found that the use of water softening sludge has been helpful in the treatment of sewage by a particular process that attained less than the maximum possible removal of polluting material from the sewage. It is quite foolish to think that water softening sludge from a municipal softening plant can be handled in a sewage plant where an attempt is being made to digest the sludge. These same comments apply to acetylene generation sludge.

Volume Fluctuations

Volume fluctuations cause no difficulty in sewers but major changes in rate of sewage flow cause considerable difficulty in sewage plant operation and the sewage plant usually has no way to iron out flows unless they have a large sewer that can be used as a reservoir. This is done in Gary, Indiana where the rate of pumping is almost constant for each 24-hour pe-

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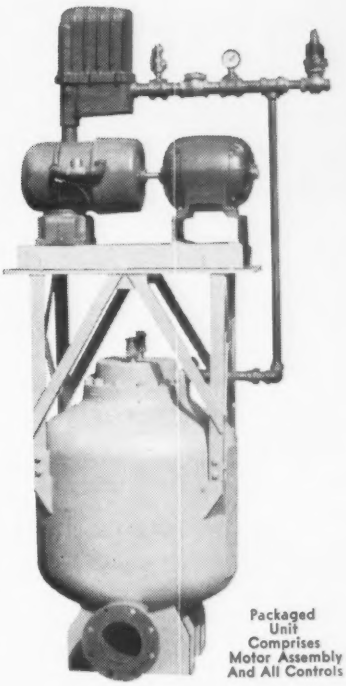

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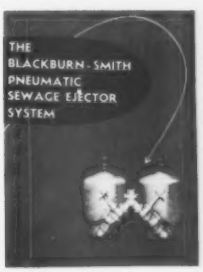

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riod. A city can hardly be expected to provide volume for leveling out variations in flow.

Temperature

Temperature of wastes may result in problems under certain conditions. If a large volume of warm water is mixed with sewage the elevated temperature may bring about rapid bacterial decomposition with the resulting odors being a nuisance. Activated sludge as well as trickling filter operation is speeded up with temperatures up to about 42°C. This statement would indicate that the addition of warm water to a sewer might be a benefit. Extremely hot water may be harmful to jointing compounds in sewers. Extremely cold water may retard bacterial action in sewage treatment plants.

The problem then arises as to a suitable way to regulate against the discharge of wastes with unusually high or low temperatures. A quart of either hot or cold water would not be harmful in any sewer, but to determine the amount that will be harmful is most difficult.

When a regulation is written stating that "wastes with temperatures higher than 150° shall not be discharged," the industries in a community are worried because they are fearful that some unreasonable municipal executive will be in authority at some time in the future and require that the industry be required to decrease the temperature of their waste water, perhaps amounting to only 1000 gallons in volume, before it is discharged into the sewers that carry a flow of a million gallons or more a day.

Acidity-Alkalinity Limits

One of the limiting factors in ordinances that is debated is that of pH limits. Bacteria that do purification work are sensitive to pH and they usually have an optimum pH at which they are most active. Therefore, variations from the optimum are detrimental to sewage treatment. The pH of sewage also is important from the standpoint of life of the sewer. Acids and alkalies are the enemies of sewers not made of vitrified materials but if the sewers are made of materials to withstand the acids and alkalies, the sewage treatment organisms are adversely affected. Many of the sewages in this country are alkaline in nature and can neutralize considerable acidity. Again we have before us the situation where it is quantity that is important and not the presence of any small amount.

Toxic Materials

The materials that are known to be toxic to bacteria are bound to be troublesome in biological treatment if there is an amount of toxic substance that will noticeably retard bacterial growth or activity. Copper, one of the metals that is known to be detrimental to organisms cannot be removed from sewage with any successful method at the present time. To expect a sewage plant to remove copper and then remove the organic matter is more than can be hoped for. The processes for removing copper and treatment of organic matter are not compatible. This, then, gives a reason for eliminating wastes from sewers if these wastes cannot be successfully treated by the process used to treat the sewage. This same reasoning applies to the other toxic substances such as chromium, zinc and cyanide.

It must be remembered, however, that some toxic substances lose much of their toxicity when mixed with sewage. Copper sulfate may be precipitated thus removing it from the liquid but it may accumulate in the sludges where it has been reported to be harmful to the digestion process.

Ordinance Limits

Some ordinances place a limit on concentration of total, dissolved and suspended solids as well as Biochemical Oxygen Demand (B.O.D.). These limitations are usually placed so that there can be an equal distribution of costs of treatment. If this is true, there should be no penalty for concentrated wastes. In fact, it costs money to handle liquid so there should be some slight advantage to a discharger if he throws away a concentrated waste, if he is paying for treatment on the pounds of solids or B.O.D. that are being discharged to the sewer system.

Many times a need is expressed for regulations because an industry is blamed for the discharge of some objectionable substance. Industries are not all "lily pure" but many of them do try to maintain a discharge from their plants that will not be injurious to the municipal sewage plant. Several years ago an industry was blamed for the lack of gas from the municipal sludge digestion tank. The findings were that there was an open valve permitting the sludge gas to escape to the atmosphere.

A meat packing plant that discharges all paunch manure to a sewer that goes to a sewage plant equipped to handle only normal amounts of grit should be informed of the difficulties being experienced. If the sewage plant must handle the paunch manure, then the industry should provide the necessary equipment to remove the paunch manure from the sewage and pay for the extra cost in handling.

Summary

From the statements and examples it might appear that there seems to be no good way to prepare regulations for the protection of sewers and sewage treatment facilities. There are, however, guiding limits that are helpful in determining what is reasonable. It is not set out anywhere whether limits should be placed on the sewage quality at the treatment works or on the effluent that is discharged by an industry. An acid discharge that corrodes the city sewer at the point of discharge to the city system is much too acid and cannot be tolerated even though the acid may be completely neutralized by the time the sewage reaches the treatment works.

The day that someone writes a perfect regulation will be welcomed by everyone. Until that day arrives it will be necessary to rely upon the good judgment of those who discharge wastes and those who are in charge of the collection and treatment of sewage.

It is apparent from the survey reported by Byrd and Gex[6] that there are situations regarding industrial waste discharges that have not been met by existing regulations. They said that 61% of the municipal respondees to a questionnaire stated that in varying degrees difficulties from industrial wastes were encountered; however, only 17% reported difficulties not solvable at the treatment plant. This seems to indicate a need for a further study of ways to write regulations so that they bring about an equitable solution to the preparation of regulations that are fair to everyone.

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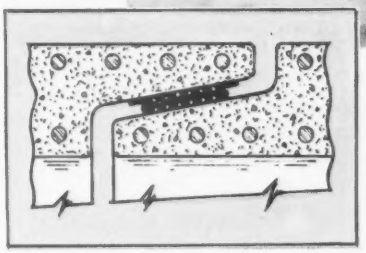

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Sanitary Sewer Extensions

by S. A. GARZA, M. C. SULTENFUSS, A. HANEMAN, Jr.

respectively, Supt. Sanitary Sewer Div., Austin, Texas; City Sanitary Engineer, San Antonio, Texas; Water and Sewer Dept., Abilene, Texas

Sewer extension policies must be administered on basically two types of properties. One type is property that is being subdivided or resubdivided and a second type is property that is an original tract, within one hundred feet of a sewer and never has been served.

Subdivided Property

In September 10, 1953 an ordinance was passed repealing several older ordinances and prescribing rules and regulations, governing plots and subdivisions of land within the corporate limits of the City and within five miles thereof. This ordinance states that a sanitary sewer shall be installed to serve each lot, in all subdivisions, where connection is to be made immediately to a community disposal system or to a public sewerage system. In the event connection to a system will not be made immediately, plans shall be prepared for future development and installation of a sewage collection system to serve each lot. Those parts of such a system which lie in streets and alleys which will be paved shall be installed prior to paving.

All work is done under the supervision and approval of the Director of the Water and Sewer Department, in accordance with the ordinances and regulations set forth by the City of Austin.

City Policy

Through a resolution passed by the City Council, the following policies govern participation by the City of Austin in the cost of construction and installation of sanitary sewers in subdivisions inside the city limits or within five miles of the limits of the City:

1. Where sanitary sewer lines of certain sizes are required to adequately serve an approved subdivision; if the cost of the lines as installed, has been approved by the City; the City will pay the extra cost incurred in constructing the larger lines, based on City estimates of the cost of the smaller lines.
2. Where both a water distribution system and a sanitary sewer system are installed in accordance with City specifications in an approved subdivision within the City; and where either system is so installed when the other system is already in place, upon the transfer of such systems to the City; the City will reimburse the subdivider to the extent of ninety per cent of the cost thereof, provided the cost thereof has been approved by the City. Upon this transfer, the City will assume maintenance and operation of such systems.
3. Where either a sanitary sewer system or a water distribution system is installed in accordance with City specifications, in an approved subdivision within the City, and the other system has not been and is not installed, upon the transfer to the City of the system so installed, the City will reimburse the subdivider to the extent of eighty per cent of the cost thereof, provided that this cost has been approved by the City.

Financing Policy

The above amounts of costs that will be reimbursed are regarded as principal. Interest thereon shall accrue annually at the rate of three per cent per annum on the unpaid balance. Interest shall accrue from the date of acceptance by the City. If both sewer and water systems have been installed by the subdivider and are transferred to the City, the City shall pay to the subdivider on or before March 1, of each year following the completion of the construction work, a sum equal to three-fourths of the amount of income realized from sales and service of water. This applies only to those customers having a direct connection to water and sewer lines within the subdivision during the preceding calendar year. Payments shall continue until the full amount of such principal due plus accrued interest has been paid *or* until payments have been made from the income so received for a period of twenty-five years from the date of completion and acceptance of the systems for which reimbursement is to be made, whichever first occurs.

These payments are made first on the interest accrued, and the remainder shall be applied to the payment of the principal.

If a sewer system or water system only is installed by the subdivider and transferred to the City, then the City shall pay to the subdivider on or before March 1, of each year following the completion of construction work, a sum equal to three-eighths of the amount of income realized from the sale of water during the preceding calendar year. This shall continue until full payment is made, plus the interest accrued, *or* until payments have been made from the income so received for a period of twenty-five years from the date of completion of the system for which reimbursement is to be made, whichever first occurs.

Areas Outside City Limits

Where both a water system and sewer system are installed in an approved subdivision outside the City

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and outside of any Water Control and Improvement District, and where either system is so installed when the other is already in place; upon the annexation of such subdivision, and the transfer to the City of both such systems, the City will reimburse the subdivider the extent of ninety per cent of the depreciated value of the systems. The value is determined by depreciating the original cost thereof three per cent per year from the date of completion of such plant to the date of annexation of the subdivision, provided the original cost of such systems has been approved by the City.

In the event either a sanitary sewer system or a water distribution system is installed in an approved subdivision outside the City and outside of any Water Control and Improvement District, and the other system has not been and is not installed; upon the annexation of such subdivision and the transfer to the City of the system so installed, the City will reimburse the subdivider to the extent of eighty per cent of the depreciated value as explained previously. Reimbursement is made under the same financing policy.

Whenever both sewer and water systems have been installed, the City will pay to the subdivider following the year of annexation of the subdivision three-fourths of the amount of income from the sale of water or until payments have been made from the income so received for a period of twenty years from the date of annexation of such subdivision, whichever first occurs. If just one system is installed three-eighths of the amount of income from the sale of water will be paid or until payments has been made from the income so received for a period of twenty years from such annexation of such subdivision, depending which occurs first.

Original Unsewered Property

On the second type of property where sewer extensions are required the following policies are followed: Each original tract within the City of Austin is entitled to 100 feet of line, provided the property can be served by such an extension and a sewer tap is paid. If more than a hundred feet is required, the property owner has three methods of making financial arrangements:

1. The property owner will take all construction costs involved and enter into a refund contract with the City.
2. The City will bear the construction cost of the first 100 feet and the property owner will bear all remaining cost with no refund.
3. The City and property owner may negotiate for a financial arrangement whereby the property owner will bear his pro rata cost and no refund contract will be required.

Extensions have been made to areas that are isolated provided the house count and their payment of sewer taps, justifies a house for every 100 feet of line that must be extended.

There are many instances where property is resubdivided and in so doing the creation of a new lot can necessitate an extension. In this case, the property owner or subdivider will have to make fiscal arrangements to serve the newly created lot or tract of land. The City in this instance will not extend the 100 feet and the owner will have to either enter into a refund contract or negotiate his pro rata cost of the extension.

Sewer Extension Policies, City of San Antonio

■ IN SAN ANTONIO at the present time, sanitary sewers are extended by five methods: 1) Bond Funds, 2) Participation, 3) New Subdivisions, 4) Township Extensions and 5) Refund Contract.

Each of these methods will be briefly discussed with advantages and disadvantages of each.

Bond Funds

At the present time, the majority of sewer line extensions are being made with bond funds. Bond funds were voted in 1955 and again in 1957 for sanitary sewer improvements. In the 1955 bond issue, $2,250,000 was voted for sanitary sewers of which $1,185,000 was earmarked for sanitary sewer extensions in unsewered areas. This work is almost complete and resulted in 112 miles of sewer extensions. The 1957 bond issued passed allocating a total of $3,350,000. Of this total, $469,810 was earmarked for extensions to serve unsewered areas, the remainder being set up for main extension and relief lines, and additions to the sewage treatment plant.

Advantages of Bond Extension

1. Areas are served that otherwise would probably never be served, particularly existing subdivisions.
2. Individual financing is no problem, as is the case with other methods.

Disadvantages of Bond Extension

1. It is not fair and equitable to those who have paid to have sewer lines extended.
2. If bond issues don't carry, sewer lines are not extended.

Participation

In this method, the people wanting a sewer extended will pay for the labor of extending the line, and the City will furnish the engineering and materials. For an eight inch line, this cost is approximately $1.00 per foot for the property owner and $1.00 per foot for the City.

Advantages

This method is a "happy medium" method of sharing costs and permits more extensions by the City.

Disadvantages

This is not fair, considering those obtaining extensions under bond programs.

New Subdivisions

Under new subdivision regulations just passed by the City, the developer is responsible for extending sewer lines within the proposed subdivision, as well as providing the main of a size based on utlimate development to connect the proposed subdivision with the existing mains. Plans and specifications must be submitted for approval and bond must be posted to assure proper construction.

Advantages

1. No cost to City.
2. Home owner pays on long term basis.

Disadvantages

1. Developer feels City should share in connection main.

Township Extensions

Sewer lines in townships connecting to the City sewer system are installed at the expense of the township. The City charges a sewer service charge for the out of town connections. Connections are presently limited to capacity of the plant and trunk lines.

Refund Contract

Under this system, which has been abolished by the City, the person installing a line has the right to charge a connection fee to anyone connecting to the line for a given period of time. The connection fee varies with circumstances.

Advantages

The City's sewer line can be extended when City funds are not available.

Disadvantages

It is not fair for some to pay for sewers and others get theirs free. People feel that once a sewer line is laid in a public street, they should be permitted to connect.

Sewer Extension Policies, City of Abilene

■ IN RECENT YEARS the City of Abilene has operated with a sewer extension policy that has been largely financed by subdividers and developers of property.

Where a new subdivision or development has been opened for building purposes, the developer is required to bear the cost of installing both water and sewer lines in accordance with plans and requirements of the City of Abilene Water and Sewer Department. The one exception to this rule is where the City has desired, for various reasons, to install sewer lines in excess of 10 inches in size. The extra cost of pipe in these instances has been borne by the City. This policy has held true both with respect to subdividing and developing of property within and without the city limits. However, where developments are outside the city limits, city limit extensions have been made to incorporate them soon after utility installations are completed.

When major trunk lines or new interceptor sewers are required to serve a new development, the cases have been handled on their own merits. Normally, the City would require the developer to bear the expense of extending the main to his property. However, the experience to date in all cases where any major extension has been involved, lines have of necessity been designed to serve other extensive areas, and the City Commission has seen fit to pay the cost of these major outfall or interceptor lines. This has eased administrative burdens concerning that property which has been developed adjacent to these major sewer main extensions.

To date, no service or connection charge has been made to developers for having these facilities provided. However, the City has considered adopting a policy whereby the developer would pay a connection fee based on area served. This charge would be in addition to the investment by the developer in the sewage collection lines within his subdivision or development.

The City's present policy has proven very effective and is accepted by the developers. A primary advantage of such a policy is that the City can make their capital investment in major interceptor, out-fall sewer lines, and treatment facilities without the necessity of expending available funds on the installation of lateral collection lines within subdivisions.

Will your bond-financed sewer system serve for generation after generation, far beyond the date the last bond is paid? Or will it have to be replaced before the bonds are retired.

The surest way to make certain today's dollars are buying generations of dependable service is to specify Clay Pipe . . . *it never wears out.* Clay Pipe does not rust, rot, corrode, or disintegrate. New long lengths with factory-made compression joints make Clay Pipe easier to install and tighter than ever before. Clay Pipe handles ground garbage, detergents, hot liquids, chemicals, acids, anything that empties into the sewer. When you specify Clay Pipe you'll never have to apologize for it or explain any failures. You'll be sure it will still be in service long after the bonds have been retired . . . Only Clay Pipe has *all* the features you can trust!

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Sewage Pump Maintenance and Operation*

by GEORGE STRUDGEON

Asst. San. Engr., Chicago Pump Co., Chicago, Ill.

PUMPS ARE the heart of the modern sewage treatment plant. Without their faithful operation treatment facilities large or small, simple or complex, would soon be uninhabitable. In order to keep this heart pumping, an effective protective maintenance program must be carried on. It does little good to start a program after a major breakdown occurs. Operating personnel must know at all times the condition of the plant equipment and immediately correct weaknesses.

Proper care and maintenance means good housekeeping. It is easier to keep equipment clean and in repair than it is to make emergency repairs when everything is covered with grease, dirt, or sludge and the various parts are rusted together.

A program of regular maintenance should be set up. One of the easiest ways to do this is to make a chart or card file showing the required maintenance operations, with a place provided to check off each item when the work is done. This chart will provide a method of reminding the responsible party when oiling, greasing and inspecting should be done, and will also provide a record of the maintenance work.

The operator should familiarize himself with the working of each piece of equipment in the plant. This can be done by studying the operation literature supplied by the equipment manufacturer. If this literature cannot be located, the operator should write for it. These booklets will also form a basis for making the maintenance chart for the plant. Cuts and drawings of the various pieces of equipment should be kept on file for reference. This material also can be obtained from the manufacturer. A drawing showing the location of all underground structures and pipe work should be kept on file for ready reference in case of trouble.

Pump Lubrication

Nothing will cripple the sewage treatment plant more quickly than a breakdown of pumping equipment. Complete understanding of pump construction and function, together with periodic inspection and repair, are essential to avoid breakdowns.

A sound maintenance program for pumps and pertinent accessories should be developed, and a regular inspection schedule adopted based on actual operating experience. To insure the best operation and care of pumps, weekly inspection and maintenance should be made of the following:

1. Bearings, for heat and noise.
2. Motors, for starting and operating speed.
3. Control equipment, for cleanliness and condition.
4. Pump operation, for vibration and noise.
5. Packing glands, for excessive leakage.

Examination of a centrifugal pump reveals that it consists essentially of only one moving part, an impeller retating in a casing. The impeller is supported on a shaft, which is in turn supported by a thrust bearing and one guide bearing. Vertical dry pit and horizontal type pumps require one guide bearing, whereas submerged type pumps require two or more bearings, depending on the depth of the wet well.

Vertical dry pit type pumps are constructed almost exactly the same as horizontal pumps. The bearings are generally of the ball type. Scrupeller pumps are fundamentally the same as horizontal centrifugal pumps, except that a stellited screw, cutting bars, and cutting ring are mounted on the suction side of the impeller for cutting up the solids before they reach the impeller.

Submerged type pumps are constructed differently from centrifugal pumps. The thrust bearing is of ball bearing construction and generally is located above the motor floor level where it will be free from floor drainage and sweepings. The pump casing, guide bearings, and shafting are extended into the wet well. Ball bearings cannot be used for guide or intermediate bearings because there is no effective means for sealing the bearings from the sewage, which would cause corrosion and rust. For this reason, submerged type pumps usually are built with sleeve type guide bearings of bronze.

Packing

One particular packing cannot be recommended for all uses. The type of packing that should be used will depend on the operator and variations in operating methods, conditions, and requirements.

Metallic and semi-metallic types of packing, together with graphite-impregnated soft asbestos, and leather, are commonly used in sewage pumps.

Soft asbestos impregnated with graphite is the most generally used packing, particularly in centrifugal and plunger type pumps. It definitely should be used where grease or water seals are not provided. On the other hand, metallic or semi-metallic packing should be used only where water or grease seals are used.

Packing containing rubber generally is not recommended because rubber has a tendency to swell when in contact with sewage.

Lubrication of the packing increases pump efficiency and reduces friction to a minimum, prolongs the packing life, and controls leakage without undue gland pressure. Where grease lubricants are used a generous quantity should be applied when the packing is installed. Thereafter, the lubricant can be applied by a hand pressure grease gun. The ideal way is to use a forced feed lubricator, applying a small but continuous amount of grease at a constant pressure.

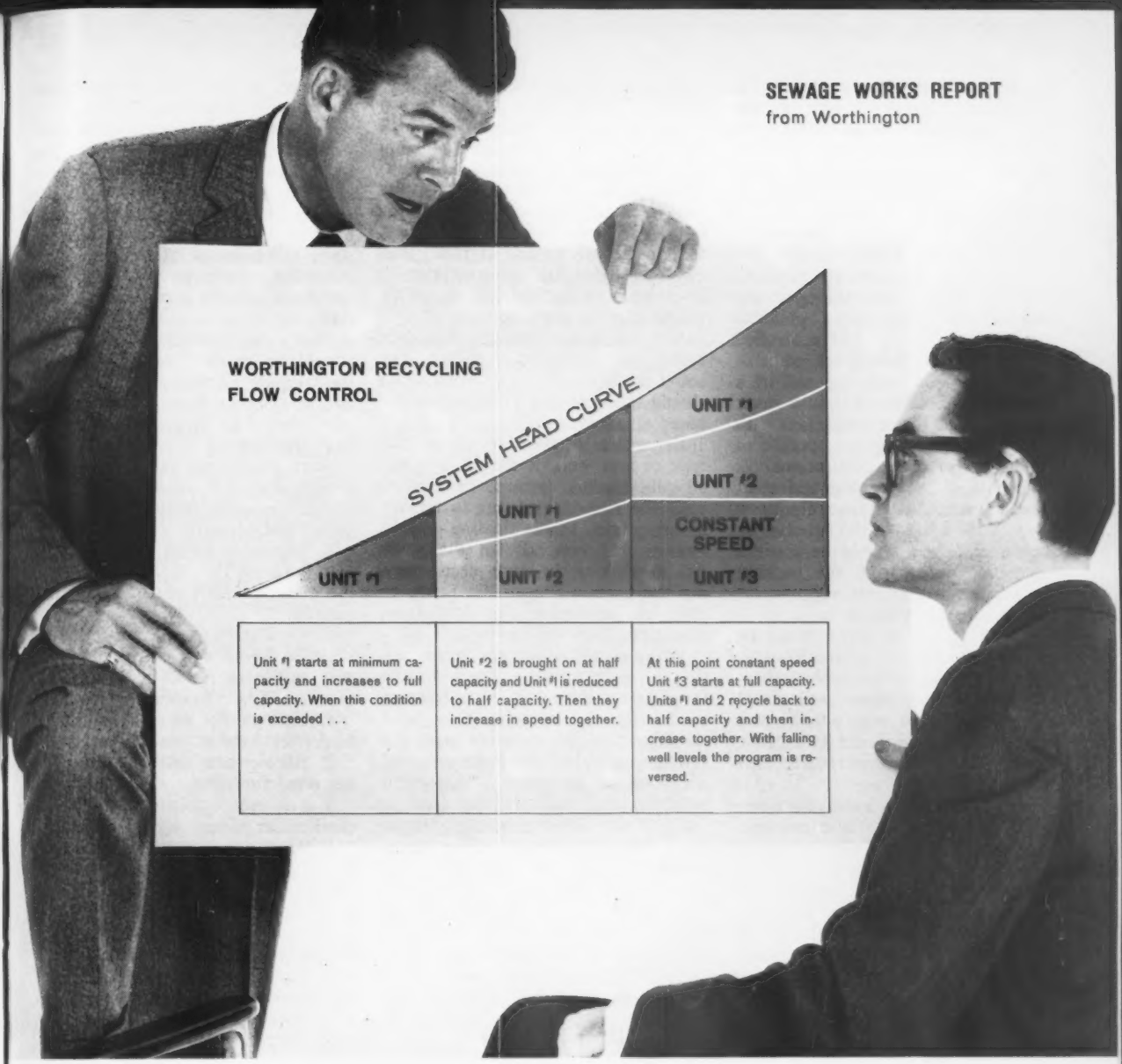
Since the packing in the stuffing box rubs against the shaft, it is just as important that it be lubricated as the bearings. In pumps handling dirty water, the packing is lubricated the same as the bearings. In pumps handling clear water, the packing is lubricated internally with the water pumped. However sewage contains grit and, therefore, cannot be used for lubrication.

Grease is used but seldom with complete success, because some grit invariably works back into the grease, imbeds in the packing, and forms a fine abrasive cloth, which soon wears out the packing and shaft sleeve. An external supply of water for the seal is the most effective lubricant.

If a grease seal is used, and the pump head does not exceed about

*Reprinted from SEW. AND IND. WASTES, 27: 506 (1955)

SEWAGE WORKS REPORT
from Worthington


WORTHINGTON RECYCLING
FLOW CONTROL
SYSTEM HEAD CURVE
UNIT #1
UNIT #2
CONSTANT SPEED
UNIT #3
UNIT #1
UNIT #2
UNIT #1
Unit #1 starts at minimum capacity and increases to full capacity. When this condition is exceeded . . .
Unit #2 is brought on at half capacity and Unit #1 is reduced to half capacity. Then they increase in speed together.
At this point constant speed Unit #3 starts at full capacity. Units #1 and 2 recycle back to half capacity and then increase together. With falling well levels the program is reversed.

Variable Speed

REDUCES SEWAGE PLANT COSTS

Why pay extra for variable speed pumping units in sewage plants?

Answer: it saves money in the long run. Here's how: (1) pumping rates are always closely matched to flow, (2) surges are avoided, (3) automatic pumping cuts costs by reducing the number of men needed, (4) the collecting well can be made considerably smaller because it can be designed for average instead of maximum flow.

The system that takes maximum advantage of the possibilities of variable speed operation is Worthington's Recycling Flow Control. Operated by a Worthington engineered control, the system maintains precise operation of variable speed pumps.

The float control will handle any number of variable speed and constant speed pumps. How it works in a plant with two variable speed and one constant speed pump is shown above.

The Recycling Flow Control is the latest development of Worthington's continuous work in the public works field. It's another reason that to get the best and the latest you should come to Worthington first. Major public works products include: pumps, comminutors, compressors, engines, and turbines.

If you would like copies of engineering discussions of variable speed pumping for sewage works, write for Bulletins RP-952 and RP-1067. Address Worthington Corporation, Section 105-5, Harrison, N. J. In Canada, Worthington (Canada) Ltd., Brantford, Ontario.

WORTHINGTON

20 ft., it should be fitted with a spring-loaded pressure type grease cup. Grease should be forced through the packing daily at a rate of 1 oz. per day. If the head is greater than 20 ft., spring-loaded pressure grease cups are not very effective. In such cases, a hand type grease gun should be applied daily.

If a water seal is used the pressure should be greater than the operating head of the pump. This pressure may be secured by a float controlled tank, located at the highest point of the building, or with the aid of a small pump. Seal water should never be obtained by direct connection with a drinking water supply, because of the danger of cross connections.

The life of the packing and shaft sleeve depend almost entirely upon the effectiveness of the grease or water seal. There should be a slight leakage of water from the packing box when the pump is running, to keep the packing cool.

A packing gland should never be tightened more than necessary. Finger-tight should be ample; otherwise excessive pressure will cause the shaft sleeve to wear rapidly and the tight packing will act as a brake band, resulting in higher power consumption.

If the stuffing box leaks excessively, remove the packing and examine the shaft sleeve. If the shaft sleeve is badly grooved or scored, it should be replaced or repaired immediately. Otherwise, the stuffing box will continue to leak excessively and regardless of how it is repacked, the packing life will be short.

When the packing becomes worn remove it entirely and thoroughly clean out the stuffing box. It is bad practice to use part new and part old packing. When repacking it is important that the first two layers are properly in place, before more is added. If this is not done, the bottom layer may be forced in unevenly and may leave a pocket to collect grit. Packing should be installed with butt joints staggered around the shaft.

Wet Wells

The size and shape of the wet well bottom are very important. If it is too flat or too large, solids will collect in the bottom and become septic. This condition may cause the presence of objectionable odors, increase soluble B.O.D., or upset the treatment plant process.

The purpose of the wet well is not to store sewage, but to provide a suction well for the pumps. Some wet wells make excellent primary tanks and defeat their original purpose.

In many cases, wet wells, which are entirely too large and function as septic tanks or primary tanks instead of as suction chambers for pumps, affect the degree of purification. Many operators have remedied this problem by cutting storage capacity through the construction of brick walls or concrete fillets, or by shortening the draw-down.

The size of the wet well should be based on the pump capacity. The active storage capacity or draw down should be equal to 1 to 1½ times the pump capacity.

Regardless of the size, shape, and type of wet well, it should be periodically drained, cleaned, and flushed with water under pressure to remove all deposits and floating solids. Grease that congeals on the walls will break loose in large pieces causing the suction line of the pump to clog, or preventing the float from operating.

When a new sewer system or section is put into service, the wet wells frequently receive large quantities of sand with the sewage. This sand should not be pumped out with the sewage pump, but should be removed with buckets as often as inspection indicates the need. If the sand is pumped out with the sewage pumps, the operator can expect earlier maintenance troubles. When effective water seals are not used the sand will get into the stuffing box packing and soon wear out the packing and pump shaft sleeve. On submerged type pumps this causes the lower sleeve bearings to wear out in a few weeks.

Electrical Control Equipment

Practically every motor is protected by a fused mainline switch and an across-the-line type starter. In addition, float switches and other control equipment may be required to automatically start and stop the motors. The fuses and thermal units used should comply with the National Electric Code or local code recommendations. The fuses and thermal units are generally rated at 125 per cent of the nameplate amperage.

The fused mainline switch and starter protect the motor against "burn out" from short circuits, grounding, high starting current, over-load, phase failure, and low or high voltage. When new motors are installed the size of the heating element in the starter should be checked against the current requirements of the motor. A starter with an oversized heating element, or with a "jumper" around the element, does not furnish protection.

If a starter with thermal protection is cutting out frequently, and the trouble cannot be located in the mechanism, location of the starter should be checked. Perhaps it is located too close to a radiator or some other source of heat. In these cases the manufacturers may recommend use of the next size thermal unit.

Every six months, the starters should be checked to make certain the tripping element is not corroded and the motor has protection. All parts should be checked for clearance and freedom of movement. If the contact points are pitted, worn, or arcing, the tips should be renewed or filed smooth, treated with petrolatum, and adjusted or lined up properly. Seriously pitted contact points may burn out the motor if they cause the motor to start and stop too frequently.

When a starter trips out, the cause must be found and corrected before the starter is reset. The following checks will help to locate the trouble:

1. The pump shaft should be turned by hand to see that it is free.
2. Wiring and controls should be inspected for loose connections.
3. Contact points should be checked for wear, pitting, or arcing.
4. Brush-type electric motors need to be checked for sparking while starting or operating, and for sticking brushes.
5. Fuses and thermal overloads should be checked for correct rating.
6. The location of fuses and thermal overload units should be checked with respect to the affect of nearby heat sources.

The switchboard should be inspected frequently and kept clean. Vibration may cause loose terminal connections, when least suspected. The insulators should be wiped clean to prevent flashover to the ground.

Dirty contacts are costly power consumers. An operator of a 0.5-m.g.d. plant was surprised to find a large reduction in his monthly power bill after thoroughly cleaning all contacts, fuses, and fuse holders.

Motors

Three-phase, squirrel cage motors are widely used in sewage treatment plants. These motors require little attention under average operating conditions. Bearing housings are packed with sufficient grease before leaving the factory to last approximately one year. Too much grease causes bearing trouble, due to excessive friction, or damage to the motor windings

caused by excess grease deposits on the insulation.

Horizontal motor bearing housings are equipped with a fitting for adding grease. Excess grease is expelled through a relief plug and thus prevents overloading. Grease should be added to motors while running. It is important that motors run long enough before replacing the relief plug to permit the rotating parts to expel any excess grease. Motor manufacturers recommend that grease be added sparingly when using a pressure gun. Periodic inspection and maintenance is necessary to assure effective lubrication.

Many motors have been damaged by overgreasing. In order to minimize this trouble, some manufacturers have designed motors with pre-lubricated sealed ball bearings and bearing housings without grease fittings. The pre-lubricated ball bearings in general purpose motors have proven satisfactory. These motors can operate 24 hr. per day for five years without greasing. Thus, periodic greasing has been reduced to one grease packing job in five years and overgreasing and grease seepage into windings has been eliminated.

Motors and control equipment installed in damp locations, such as underground pump stations, have been damaged seriously by excessive condensation. The best cure seems to be the installation of a small blower of adequate capacity to change the air as often as necessary to eliminate condensation. Gravity ventilation by means of pipe openings has often proved to be inadequate. Humidity in the control box is best controlled by installation of a dehumidifier or strip heater elements in the box.

It is good practice to blow dust, dirt and other accumulations from motor windings with compressed air. The air should be free of excessive moisture and the pressure should not exceed 80 p.s.i. The frequency will depend on the location and type of motor.

Frequent starting and stopping of electric motors is detrimental. The starting current of a motor is generally several times its full load current, and will store up heat in the windings. A similar condition is caused by overloading motors. The excess heat in the windings will bake out the insulation, causing it to become dry and brittle with eventual flaking off and failure.

Where motors are installed in hot locations consideration should be given to the use of oversize motors. These motors, working below maximum capacity would be less likely to seriously heat.

Should a motor be submerged, the bearings should be immediately removed and dried to prevent them from rusting. The motor should be sent to the repair shop for a thorough cleaning, and be baked out befor it is put back into service.

For satisfactory electric motor operation, regardless of the type of motor, the following should receive a weekly check:

1. The motor shaft for freedom from oil and grease.
2. The oil level in bearings.
3. The speed and direction of rotation.
4. The commutator and brushes.
5. The tightness of all wiring connections.
6. The interiors and exteriors of the motor for freedom from moisture, oil and dirt.

Semi-annual checks should include:

1. Draining and replacement of the oil in sleeve bearings and gear box.
2. A check of the grease in ball or roller bearings.

The ball or roller bearing housings should be cleaned out and greased annually.

By using these basic maintenance checks on a regular schedule, the heart of the sewage treatment plant will be kept in a serviceable pumping condition.

Lagoon System of Sewage Disposal

by PAT THOMSON

County Engineer, Douglas County, Waterville, Wash.

MODERN SEWAGE DISPOSAL does not have to have dirty, odoriferous conditions. Yet, clean odorless disposal does not necessarily have to be accomplished through the conventional type of filtration treatment. In fact, it has been proven that an unconventional type can serve the small town as efficiently as standard units, and at a smaller cost, both initially and maintenance-wise.

The small town of Waterville, Wash., population 1,000, was faced with a difficult problem. The eastern portion of the town had been sewered sometime in the past under individual local improvement district projects. The western portion of the town, rightfully, also desired the advantage of sewage facilities. However, the Washington State Health Department would not approve the additional facilities without better, more efficient, appropriate methods of disposal.

To ascertain the extent of the problem before the council, Helmer-Hughes, Wenatchee consulting engineers, were engaged to make a survey of the present system, the needed system, and the necessary disposal unit.

This revealed the existing facilities to consist of 16,385 linear feet of 6-inch and 1,315 linear feet of 8-inch collection sewers, 6,185 feet of 8-inch main sewers, and 5,000 feet of 8-inch outfall sewer. Treatment consisted of septic tanks of various capacities and construction, located at the ends of the branch sewers. Effluent from these septic tanks discharged to main sewers and then to the outfall sewer with an outlet to Corbaley Creek.

Recommended Program

No regular program of cleaning and maintaining had been possible in the past. Hence, the effluent from the various septic tanks varied widely, being very turbid, with a bad odor, and a high percentage of solids. The recommendation called for the construction of a local improvement district in the western portion of town, a new outfall line, trunk lines, and a disposal unit.

From the standpoint of cost, a disposal type new to the Pacific Northwest was considered. This is the process known as lagooning. Correspondence and photographs showed that this process had been highly successful in the Central and Midwestern States. It is attractive as a final disposal method because the cost is considerably less than that of other conventional infiltration methods.

The process requires three main points: plenty of sunshine, consistent breezes, and a wide open area of clay or other water-retaining soil.

Lagoon operation is simplicity itself. Raw sewage enters the water-filled lagoon approximately at the center, slightly above subgrade elevation. The lagoon is placed strategically in relationship to the prevailing winds. Thus, wind action and the resultant wave action cause the raw sewage to move over the lagoon area, preventing a piling septic condition. A lagoon pond of 3- to 5-foot depth represents optimum conditions for wind and wave action, yet it is deep enough to prevent total-depth freezing in most climates.

As the raw sewage spreads thinly over the lagoon bottom, digestion begins almost immediately. The broken particles of sewage are attacked by both aerobic and anaerobic bacteria. Algae growth in the water causes a supersaturated oxygen condition. This tends to give a fast con-

DURING early lagoon operation evaporation equaled inflow and filling was slow

sumption of organic sewage carbon compounds. Sewage digestion and purification is good, reported reaching from 65 percent in the dormant winter months to 98 percent in the summer months.

Method of Financing

It was now time to establish financing. Two separate bond issues were used. The local improvement portion is assessed directly against the property especially benefitting from the lateral sewer improvement. The owner may pay this by:

1. Paying cash within 30 days of final notice without interest.
2. In ten equal installments of principal with 5 percent interest.
3. In installments and interest for a number of years, then paying the balance and interest at the next anniversary.

This local improvement district (LID) assessment is a lien against the property second only to general taxes. The city must establish a guarantee fund from a levy out of the 15 mils, guaranteeing the payment of interest should collections be insufficient. Legality requires that LID bonds be sold at not less than 100 par. If such is not done, the contractor is required to take them in his payment. In that case, his bid will cover any discount he must suffer in peddling them. Original assessment costs were determined as $1.89 per front lot foot with a $100 minimum hookup charge per unit.

Sewage revenue bonds pay for the portion benefitting the entire community and not one specific area. These bonds will be repaid, principal and interest, from the sewer revenues and no other source. The revenues obtained from the monthly sewer charge made against each residence and business structure will first be used to defray the expense of operating and maintaining the sewer system, and then to pay the principal and interest of the sewage revenue bond issue.

The sewage revenue bonds will be repaid in annual installments over a 20-year period, with the right of the town to pay them off faster than the stated maturity on and after five years from the date of issuance.

The town agrees to charge rates for sewer service that will produce sufficient revenues to operate the system, and then provide not less than 1.4 times the principal and interest requirements that year on the sewer revenue bonds. The surplus thereby created may be used to expand the system, or applied against the bond issue on or after the option date. This procedure could well retire all of the revenue bonds by 1970, several years ahead of the stated maturity date. Monthly use charge was determined at $2 per month per residential unit, and $4 per month per business unit.

D-7 TRACTOR pulling carryall labors in muddy muck trench during lagoon construction.

Bids were called April 11, 1956, with Goodfellow Brothers, Inc., Wenatchee, Wash., the low bidders with an amount of $84,510.94. This was awarded, with work commencing on May 1. The project was completed August 23, for an amount of $98,-171.45. This was an over-run of $13,-660.51, caused by $3,279.72 in extra work orders, 10,000 cubic yards of extra lagoon excavation, and 1,332 cubic yards of rock trench excavation. The final estimate was paid on September 1. Of the total contract, $22,518.57 was the LID system, giving a final front footage charge of $114 per linear foot, or $0.75 less than anticipated.

Lagoon Area Problems

The lagoon was in a natural basin known as Corbaley's Pond. Although the area was surface dry, once the crust was broken it didn't take long to determine why there was such a rank growth of marsh grass. Just about the time the first "cat" went out of sight in the lagoon area, construction commenced on the outfall line with a solid rock cut.

To complicate matters more, an unheard-of stratune of water showed up in the rock trench. Have you tried laying sewer pipe lately in a trench where a spring bubbles faster than two pumps can handle the inflow? It is somewhat discouraging when you can't lay a manhole faster than the rising waters.

It was also necessary that the contractor exercise care on the 6,000 feet of outfall line. Most of this was through wheat land, damaged crop had to be paid for, and no indiscriminate shifting of equipment could be allowed. Land had to be left in a suitable condition for harvest and future farming activities. Only the minimum of leveling was permitted for trencher travel.

Lagoon dike construction was of organic-free material placed in 6-inch layers compacted by sheepsfoot

OUTLET BOX, with space for chlorination unit if effluent control tests show necessity.

LATERAL lines were placed quickly and efficiently, with the least possible disruption to traffic. Pipe laying is right on heels of digging crew.

rollers. Utilization of the lagoon began in June at the commencement of one of the region's driest seasons. It had originally been hoped to hit the season when rain, snow, and extra pumping could help fill the lagoon. During the months of July and August seepage, sun, and wind evaporation about equaled the inflow. Therefore, a portion of the lagoon had to be diked transversly to allow one portion to fill more rapidly. Still, even on the hottest day of the year, under the most adverse operating conditions, the lagoon gave off no detectable disagreeable odors.

During design, both the State Health Department and the Pollution Control Commission expressed the desire to have influent and effluent flow measuring devices in the outfall line and lagoon discharge. Original plans included a Cipolletti wier in both locations. However, the pollution Control Commission required that the influent wier be changed to a Parshall flume. Thus, an Armco metal 6-inch throat Parshall flume was installed in a concrete structure just above the lagoon entrance of the outfall line, including gage wells and recording meter pits. Meters are to be provided by the state if deemed necessary.

Chlorination was not put in, for until the effluent can be tested for a period, there is no way of knowing how much or to what degree this added treatment must be provided. Space is provided, however, for a contact chamber and a hypochlorinator as being best adapted to the requirements.

Other Problems

Topography was such that one area had to be served with a lift station. This was of the standard manhole type, containing two Fairbanks-Morse vertical motor, sleeve bearing, non-clog, wet pit sewage pumps. Each pump is capable of delivering 50 gpm against a total dynamic head of 30 feet at a maximum allowable 1,800 rpm. All openings are large enough to permit passage of a 1.5-inch sphere. Pumps are automatic through the operation of a switch float set for predetermined liquid level. Two gravity lines lead into the pumping station back through a central pressure pipe.

In connecting with the old sewer lines, some interesting things developed. One old line, about 350 feet in length, had been constructed of tin irrigation pipe. When it was opened to be tapped, there was nothing, for the pipe had long since rotted away. The only reason the opening remained so was the constant flow of liquid. This replacement involved additional line, creating grade problems because it was desired to shorten the distance as much as possible.

In another instance, the old line was on almost a level grade. It took a painted marker 1 1/2 hour to travel 300 feet. With the additional facilities introduced through the new line, if two were flushed simultaneously, someone had to "man the decks" for a calamity. So another extra work order went into effect.

Probably the most disappointing aspect, from the contractor's viewpoint, was the cement clay structure encountered in excavating for the lateral lines. If the contractor blasted, there was the considerable expense of suitably backfilling the resultant wide ditch, then redigging for pipe laying. If the contractor didn't shoot, the cement clay beat men and equipment to bits at unclassified excavation yardage rates. This one factor alone probably caused the most grief.

Ingenious Solution to Forming Problem

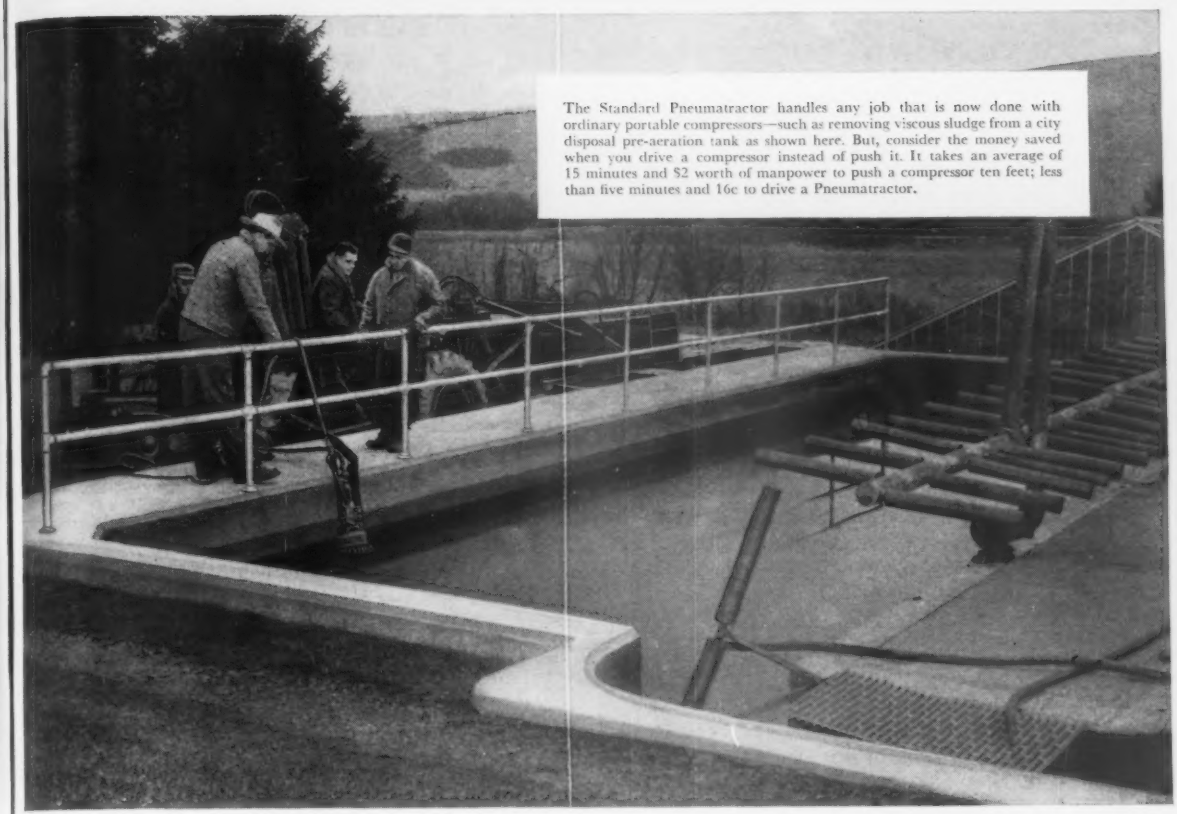
One problem was solved uniquely. The flat slab of the pressure pump pit had to be fitted with a standard circular manhole cover. This presented a forming problem for a circular form that was smaller than the opening and easily removable. This was solved by using the wooden ends from telephone lines reels, somewhat smaller in diameter than a manhole cover. Four of these, each 2 1/2 inches thick, were spiked together, giving proper depth. These were then wrapped with rope until the desired diameter was obtained. The whole was then covered with a light tin, nailed through the rope with lath nails, leaving one rope end free. Once the concrete was set, the free rope end allowed unraveling of the rope and removal of the wooden disks. Presto! A perfect circular opening in any flat slab.

In evaluating the construction of any public utility, the prime consideration is best service for least cost. For Waterville, the lagoon system was some $60,000 cheaper than the conventional tank system would have been. When this was written, the lagoon had been functioning properly and efficiently. Thus, the prime duty has been fulfilled.

The system has been in operation for 16 months. It has successfuly weathered one of the worst winter conditions this area has seen since 1916, with temperatures ranging to —10°F and a total snowfall of 121 inches. During August, three roaring cloudbursts caused extensive road and field damage. None of these weather conditions hindered the efficient operation of the lagoon.

Flocks of ducks and geese have used the lagoon as a feeding resting place on both fall and spring migrations. Small bird life is abundant. The only animal problem has come from several families of muskrats moving into one end of the lagoon intent upon establishing permanent housekeeping. Although trapped and removed to other waters, they insisted on returning, establishing burrows in the dikes. Otherwise, the biggest maintenance factor has been mowing the weeds on the dikes, which have not yet been seeded to grass. One section of woven wire fence that a deer thoughtlessly ploughed into had to be rebuilt.

The Waterville lagoon has provided a useful, economical, cheaply maintained sewage treatment system, operating without fuss or muss. Since this community pioneered lagoon installation in the Northwest, four others have been constructed in the immediate vicinity and more are being planned.



The Standard Pneumatractor handles any job that is now done with ordinary portable compressors—such as removing viscous sludge from a city disposal pre-aeration tank as shown here. But, consider the money saved when you drive a compressor instead of push it. It takes an average of 15 minutes and $2 worth of manpower to push a compressor ten feet; less than five minutes and 16c to drive a Pneumatractor.

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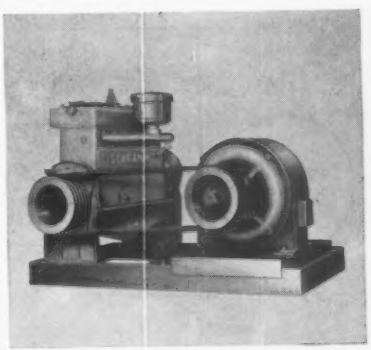
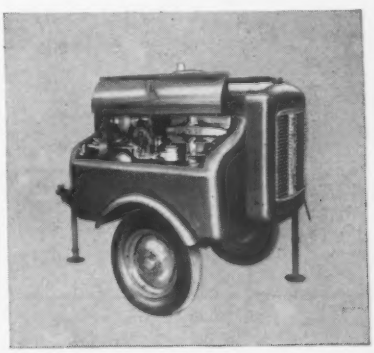


Stationary Compressors—electric motor or V-belt drive. Vibrationless operation—no foundation needed. From 50 to 600 cfm.



Portable Compressors—Models from 20 to 600 cfm—choice of gasoline or diesel engine in most models. Also a complete line of air tools available.

High-Rate Sewage Treatment

by D. W. RYCKMAN and E. EDGERLEY JR.

respectively Assoc. Prof. and Asst. Prof. of Sanitary Engineering, Washington University, St. Louis, Mo.

The term "high rate" has been used to describe activated sludge treatment processes, filtration of sewage, clarifying units, sludge digestion methods, and patented processes.

To make the situation worse, "high-rate" is also a well-known term to describe methods of water purification. When one sees the caption "High-Rate Filter Performance," he cannot be sure whether it pertains to methods of sewage treatment or to water purification.

Review of the fundamentals involved in the so-called "high-rate sewage processes," should greatly simplify the problem, and perhaps show that the phrase, "There is nothing new under the sun," fits the situation. Therefore, a study of the fundamentals of the various high-rate sewage treatment processes is presented, but the discussion is limited to the aerobic processes of high-rate activated sludge, high-rate trickling filters, and so-called high-rate package units.

High-Rate Activated Sludge

A schematic flow diagram for high-rate activated sludge systems is presented in Figure 1. It should be noted that the basic flow diagram is the same as that for the conventional activated sludge process. However, considerably less sludge is returned to the aeration tank. This accounts for the lower suspended solids content maintained in the aeration tank, one of the main characteristics of the high-rate activated sludge process.

The aeration solids employed for treating domestic sewage range from 250 to 700 mg/L suspended solids, approximately 5 to 10 per cent return sludge on total flow basis. B.O.D. removals of from 57 to 76 per cent have been reported by Torpey[1] and a 2½ to 3 = detention period is used in the aeration basins. With a short detention period and low suspended solids content, the ratio of food concentration to microorganisms is very high, thus the rate of biological activity is very high. With this relatively high food concentration the microorganisms carry quite a bit of food with them to the final clarifiers, which results in an active return sludge with a high-rate of oxygen utilization. Approximately 50 per cent of the activated sludge is returned to the aeration tank.

Rates of Biological Activity And Growth Phases

The biological activity involved in the high-rate activated sludge process is best understood with a knowledge of a typical growth curve. Figure 2 shows a growth curve of activated sludge and trickling filter slimes. The initial conditions are that the food concentration is high and the mass of microorganisms is relatively low. Because in the activated sludge systems suspended solids are commonly used as the measure of the quantity of microorganisms, the mass of organisms is plotted versus time for the system.

During the logarithmic growth phase if sufficient nutrients as recommended by Sawyer,[2], are present the only limiting factor is the generation time of the microorganisms. This is the growth phase utilized in the high-rate activated sludge process. During this growth phase the mass of microorganisms will increase at a log-

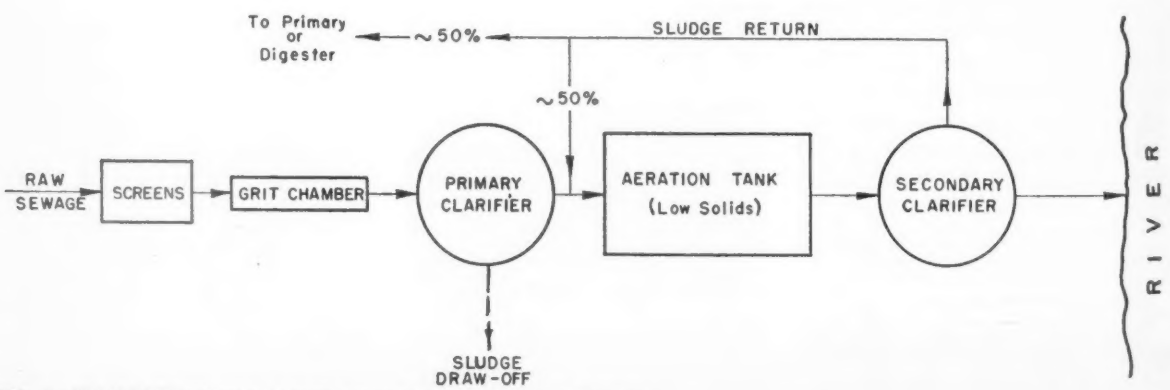


FIG. 1—HIGH RATE activated sludge process follows this flow diagram.

arithmic rate and continue to do so until food concentration becomes a limiting factor. This is the beginning of the phase known as declining growth.

During the declining growth phase the mass of microorganisms increases at a decreasing rate, until they reach a *status-quo* condition where the rate of increase of microorganisms is equal to the rate of lysis of the cells. At this point the growth phase is referred to as endogenous. During the endogenous phase the microorganisms derive their energy from lysed cells, therefore, the mass of microorganisms steadily decreases.

The relationship of these growth phases to the high-rate activated sludge process may be understood by studying the function of sewage treatment which may partially be expressed by:

$$\text{Organic Compounds} + \text{Microorganisms} + O_2 \rightarrow \text{More Microorganisms} + CO_2 + H_2O$$

As indicated, the organics are converted to carbon dioxide and water and more microorganisms. The only problem that remains for the sanitary engineer is to extract the microorganisms from the system. This usually is accomplished in the final clarifier.

Referring to the typical growth curve in Figure 2, it may be seen that the organics are removed from the system most rapidly during the logarithmic growth stage. However, in order to produce a highly clarified effluent the engineer must provide a means for removing the biological flocs formed during the process.

McKinney[3] has demonstrated that this is done most efficiently when the energy level of the system is lowest. Non-flocculent growths are produced during the logarithmic phase, and only partial flocculent growths during the declining growth phase, while best flocculation is accomplished during the endogenous stage. Thus, the engineer must choose the particular environment necessary to solve the problem with which he is confronted.

Rates of Oxygen Utilization And Growth Phases

The oxygen utilized by a batch-fed activated sludge system was measured with a Warburg respirometer.[4] The results (Fig. 3) show that initally the rate of oxygen uptake increases rapidly, until it reaches the point where food becomes a limiting factor.

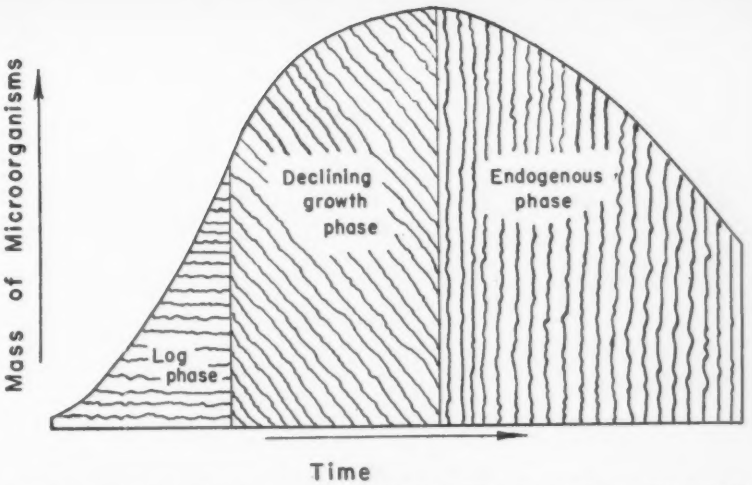


FIG. 2. Growth of activated sludge and trickling filter slimes follows this typical growth curve.

This initial period corresponds to the logarithmic growth stage.

During the declining growth stage the rate of oxygen uptake continually decreases until it reaches a constant value, which corresponds to the beginning of the endogenous phase. During this endogenous phase, the rate of oxygen uptake is approximately the same as the rate of oxygen uptake of an activated sludge blank. The sludge blank system illustrated in the lower curve in Figure 3 is similar in all respects to the system

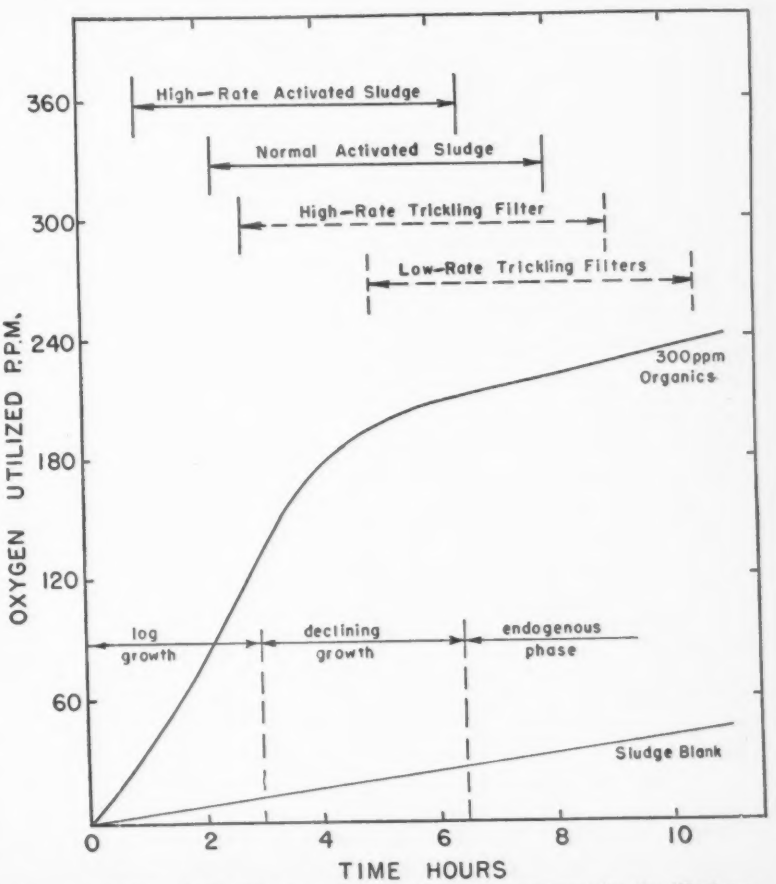
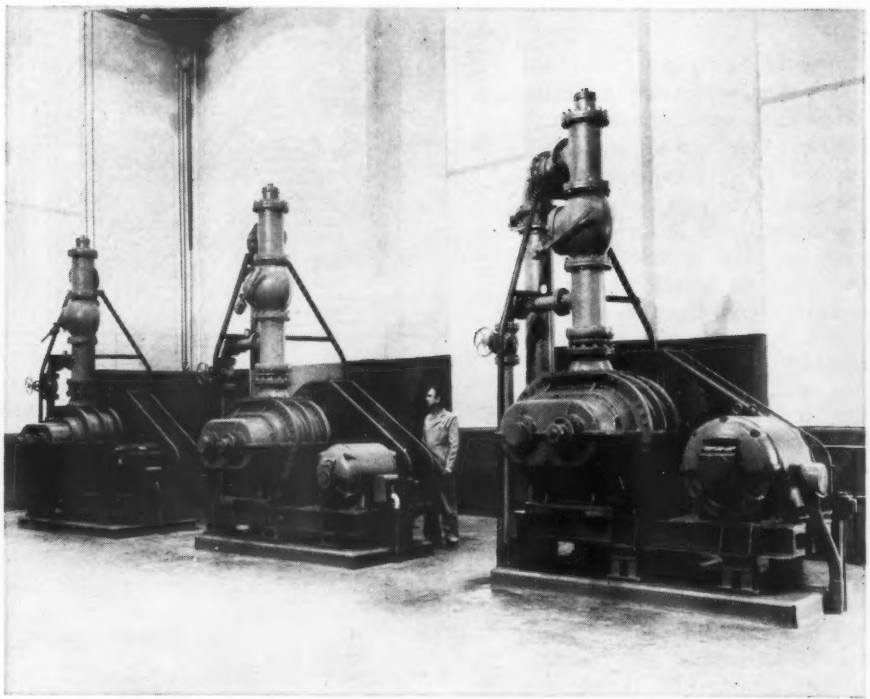


FIG. 3. OXYGEN relationships in activated sludge as measured by the Warburg respirometer.

SUTORBILT BLOWERS

GAS AND VACUUM PUMPS



These three 18 x 18 heavy duty Sutorbilt blowers operate at 350 r.p.m., delivering 2,400 c.f.m. against 7 psig. Motors are 100 hp.

SUTORBILT ROTARY POSITIVE PRESSURE BLOWERS

Size	Dia. Inlet & Outlet	Blower Disp. CFR	Maximum Pressure	SERIES 400				SERIES 600			
				Blower Wt. Net Lbs.	Maximum RPM	Maximum CFM	Maximum HP	Blower Wt. Net Lbs.	Maximum RPM	Maximum CFM	Maximum HP
LOW PRESSURE BLOWERS											
10 x 24	10"	3.3	3.0	2230	770	2294	36.0	2700	1200	3713	57.0
12 x 30	12"	6.0	3.0	3700	640	3450	54.0	4200	1000	5640	86.0
14 x 37	14"	10.0	3.0	5400	550	5000	79.0	5900	900	8500	128.0
16 x 43	18"	15.0	3.0	7500	480	6525	103.0	8100	720	10,125	154.0
18 x 42	18"	18.7	3.0	9200	425	7200	113.0	9800	650	11,407	173.0
20 x 55	24"	30.0	3.0	11,400	390	10,800	166.0	12,100	600	16,950	256.0
22 x 60	24"	40.7	3.0	17,200	350	13,187	202.0	17,900	515	19,740	399.0
MEDIUM PRESSURE BLOWERS											
10 x 18	10"	2.5	6.0	2000	770	1663	55.0	2400	1200	2725	86.0
12 x 20	12"	4.0	6.0	3200	640	2220	72.5	3700	1000	3640	114.0
14 x 23	14"	6.2	6.0	4300	550	2976	97.0	4800	900	5146	159.0
16 x 26	16"	9.0	6.0	5900	480	3780	122.0	6500	720	5940	185.0
18 x 30	16"	13.0	6.0	7400	425	4862	156.0	8100	650	7735	241.0
20 x 31	20"	17.0	6.0	8650	390	5865	190.0	9400	600	9435	290.0
22 x 36	24"	24.0	6.0	13,830	350	7440	240.0	14,530	515	11,400	352.0
HIGH PRESSURE BLOWERS											
10 x 11	8"	1.5	10.0	1700	770	945	55.0	2100	1200	1590	86.0
12 x 13	10"	2.6	10.0	2700	640	1378	79.0	3200	1000	2314	124.0
14 x 15	10"	4.0	10.0	3700	550	1840	104.0	4200	900	3240	171.0
16 x 17	12"	6.0	10.0	5000	480	2400	136.0	5600	720	3840	205.0
18 x 18	14"	8.0	10.0	6500	425	2840	161.0	7200	650	4640	247.0
20 x 20	16"	11.0	10.0	7500	390	3685	204.0	8200	600	5995	313.0
22 x 22	18"	15.0	10.0	11,700	350	4500	250.0	12,400	515	6975	367.0

SUTORBILT CALIFORNIA SERIES

Operation — Two figure-eight impellers rotate in opposite directions, providing rotary, positive displacement. Impellers are separated by minute clearance, and deliver a *metered* volume of air or gas. Clearances are maintained by rugged, precise timing gears.

Construction — Rugged cases, headplates and impellers are machined of close-grained cast iron. Impellers are pressed and keyed securely to the shaft and are accurately balanced to operate without vibration. Large alloy steel shafts are ground and polished. Bearings are heavy duty anti-friction type. Wide face gears are made of semi-steel and run in a bath of oil.

Drives — The recommended drive for Sutorbilt blowers or gas pumps is by single or multiple V-belt. The V-drive facilitates changes of speed to accommodate variations in operating requirements.

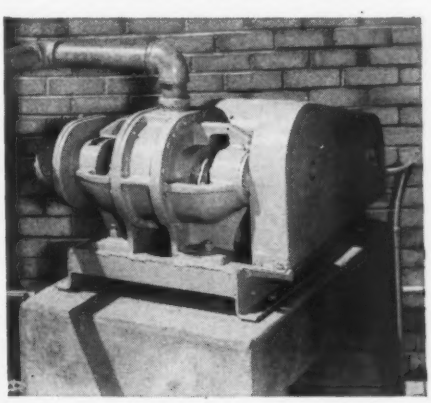
Pressure Relief Valves

Weighted Type—Made in 1", 2", 3" and 4" sizes, are chatterproof and adjustable to ¼ pound increments by adding or removing weights.

Vacuum, Spring-Loaded Type—Made in 1½", 3", 4" and 6" sizes. Changes in operating conditions are easily accommodated by adjusting spring tension. Optional equipment.

Timing Gears — Sizes 5" and larger are fitted with wide-face herringbone gears and the exclusive Sutorbilt Timing Hub. Sizes 2" to 4" are fitted with spur gears and no timing hub. The exclusive Sutorbilt timing hub enables user to easily retime unit in the field. Should any foreign object lodge between the impellers, the shear pins in the hub will yield, preventing any major parts damage. Timing hub has great shock-absorbing qualities.

Thrust Bearings — For special conditions, Sutorbilt blowers or gas pumps can be fitted with a single or double thrust bearing assembly. The thrust bearings control lateral position of the impellers in relation to the headplates, countering unusually severe thrust. This prevents the impellers from floating against either headplate, causing undue wear and subsequent loss of efficiency.



Model 5HXB vacuum pump handling sewer gases in sewage treatment plant.

Blower Number	Diameter Inlet and Outlet	Blower Disp. Cu. Ft. Rev.	Diameter Shafts	Approx. Weight	Net Capacities in Cubic Feet per Minute of FREE AIR or 1.0 Sp. Gr. Gas at the SPEED and PRESSURE									
LOW PRESSURE					Blower RPM	½ Pound CFM	HP	1 Pound CFM	HP	2 Pounds CFM	HP	3 Pounds CFM	HP
2-L	2 "	.034	.625	30	1200	33	.10	30	.19	25	.39	21.5	.58
					1750	52	.14	49	.28	44	.56	40	.85
					2480	77	.20	73	.40	69	.80	65	1.2
3-L	2½"	.094	.750	76	1160	93	.26	86	.52	77	1.1	70	1.55
					1500	125	.34	119	.67	110	1.4	102	2.0
					1770	151	.40	144	.79	135	1.6	128	2.4
4-L	3 "	.16	.875	120	900	122	.34	114	.68	102	1.4	92	2.1
					1160	164	.44	155	.88	143	1.8	133	2.7
					1550	228	.59	218	1.2	206	2.4	196	3.6
5-L	4 "	.34	1.125	230	700	208	.57	195	1.1	177	2.3	164	3.4
					1000	310	.81	296	1.6	278	3.2	265	4.9
					1240	390	1.0	378	2.0	360	4.0	346	6.0
6-L	6"	.70	1.375	460	500	308	.83	290	1.7	266	3.3	248	5.0
					750	482	1.3	465	2.5	441	5.0	423	7.5
					1030	680	1.7	670	3.4	636	6.8	620	10.0
7-L	8 "	1.2	1.562	700	500	530	1.4	510	2.9	470	5.7	445	8.6
					700	770	2.0	750	4.0	710	8.0	680	12.0
					890	1000	2.5	970	5.0	940	10.0	910	15.2
8-L	8 "	1.7	1.750	1150	670	1060	2.7	1030	5.4	980	10.8	950	16.2
					850	1370	3.4	1340	6.8	1290	13.7	1260	20.5
					1000	1620	4.0	1590	8.1	1560	16.1	1510	24.2
MEDIUM PRESSURE					Blower RPM	3 Pounds CFM	HP	4 Pounds CFM	HP	5 Pounds CFM	HP	6 Pounds CFM	HP
2-M	1 "	.017	.625	25	1200	11	.29	9	.39	8	.49	6.8	.58
					1750	20	.43	18	.57	17	.71	16.5	.85
					2480	32	.60	31	.80	30	1.0	28.5	1.2
3-M	2 "	.055	.750	61	1160	41	.91	38	1.2	35	1.5	32	1.8
					1500	59	1.2	56	1.6	53	2.0	50	2.4
					1770	75	1.4	71	1.9	68	2.3	65	2.8
4-M	2½"	.11	.875	97	900	63	1.4	57	1.9	53	2.3	48	2.8
					1160	92	1.8	86	2.4	81	3.0	77	3.7
					1550	135	2.4	129	3.2	124	4.1	120	4.9
5-M	4 "	.18	1.125	195	700	86	1.8	81	2.4	75	3.0	70	3.6
					1000	140	2.6	135	3.4	129	4.3	124	5.1
					1240	184	3.2	178	4.3	172	5.3	167	6.4
6-M	5 "	.37	1.375	310	500	131	2.6	122	3.5	114	4.4	110	6.1
					750	222	3.9	214	5.3	206	6.6	200	7.9
					1030	326	5.4	318	7.3	310	9.1	303	10.8
7-M	6 "	.73	1.562	525	600	342	6.2	328	8.3	314	10.4	300	12.5
					750	452	7.8	437	10.4	424	13.0	412	15.6
					890	555	9.3	540	12.4	525	15.5	515	18.6
8-M	6 "	1.02	1.750	900	670	572	9.7	555	13.0	540	16.2	527	19.5
					850	756	12.4	740	16.5	724	20.6	712	24.8
					1000	915	14.6	890	19.4	876	24.2	865	29.0
HIGH PRESSURE					Blower RPM	7 Pounds CFM	HP	8 Pounds CFM	HP	9 Pounds CFM	HP	10 Pounds CFM	HP
3-H	1¼"	.04	.750	56	1160	21.2	1.5	19.5	1.8	18	2.0	16.5	2.2
					1500	35	2.0	33	2.3	31	2.6	30	2.8
					1770	45	2.4	44	2.7	42	3.0	41	3.4
4-H	1½"	.07	.875	85	950	32	2.2	29	2.5	27	2.8	25	3.2
					1160	46	2.7	43	3.1	42	3.5	40	3.9
					1550	72	3.6	70	4.1	69	4.6	67	5.2
5-H	2½"	.12	1.125	170	750	50	3.0	47	3.4	44	3.8	42	4.3
					1000	80	4.0	77	4.6	74	5.1	72	5.7
					1240	108	4.9	105	5.7	103	6.4	101	7.1
6-H	2½"	.22	1.375	280	700	104	5.1	101	5.9	98	6.6	95	7.3
					850	137	6.2	134	7.1	131	8.0	127	8.9
					1030	177	7.5	174	8.6	170	9.7	167	10.7
7-H	3 "	.35	1.562	420	650	158	7.5	153	8.6	148	9.7	144	10.7
					800	210	9.3	206	10.6	200	12.0	197	13.3
					890	242	10.4	238	11.8	232	13.2	228	14.8
8-H	4 "	.55	1.750	710	670	278	12.2	272	14.0	266	15.7	260	17.5
					850	376	15.5	370	17.8	365	20.0	360	22.2
					1000	460	18.3	453	21.0	447	23.4	442	26.2

For Delivery at Other Speeds—Add or subtract Blower or Gas Pump Displacement. Bulletin S-65C describes larger units than Table 1 above.

1952
S-22

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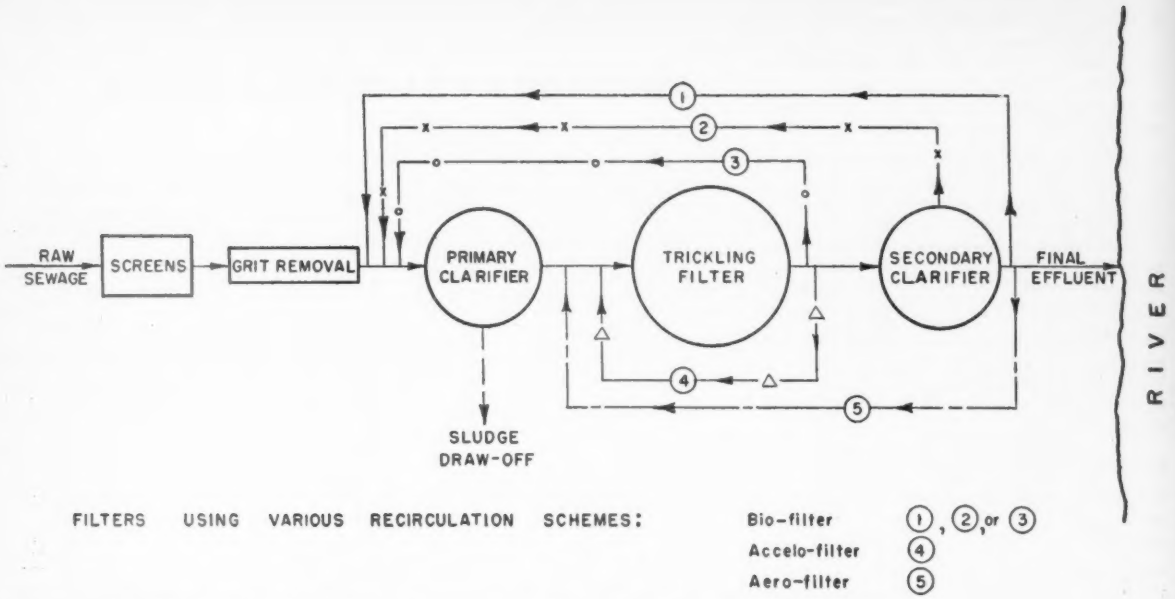

FIG. 4—HIGH RATE one stage trickling filter process operates according to this flow diagram.

illustrated in the upper curve, except that the sludge blank system did not receive the initial feed of organics.

It may be seen that the high-rate activated sludge system utilizes primarily the logarithmic growth phase, and a portion of the declining growth phase. The normal activated sludge system utilizes only a small portion of the logarithmic growth phase, operates primarily in the declining growth phase, and extends into the endogenous phase. Thus, the high-rate activated sludge system employs the advantage of a higher rate of removal of organics from the system.

Because the high-rate process does not extend into the endogenous phase, less ideal conditions for flocculation exist than in the normal activated sludge processes. This explains the lower B.O.D. removal percentages reported for the high-rate activated sludge systems. In other words, less efficient floc formation yields inefficient settling in the final clarifier, thus a higher B.O.D. in the final effluent.

Advantages and Disadvantages

Some of the advantages claimed[1] by the high-rate activated sludge systems are:

1. Savings of aeration tank volume.
2. Savings in air requirements (0.3 cu ft per gal instead of 1 cu ft per gal in normal process).
3. Flexibility of effluent quality (60 to 80% B.O.D. removal).
4. Faster recovery from shock loads (the lower the sludge age, the shorter the recovery period).
5. With weak raw sewage the primary clarifier may be eliminated.

Some of the disadvantages reported[1] are:

1. Operations must be carefully controlled.
2. Effluent quality varies during the day.
3. Final settling tank sludge must be removed as quickly as possible, because the sludge is very active.

These advantages and disadvantages appear reasonable on the basis of the information derived from Fig. 2 and 3.

High-Rate Trickling Filters

The basic principles of high-rate trickling filters may be studied by considering the flow diagram for the one-stage treatment plant shown in Fig. 4.

The main characteristics differentiating the high-rate from the low-rate trickling filter is the employment of recirculation of trickling filter effluent or settled trickling filter effluent.[5] A primary advantage of this system is that through recirculation the contact time during biological stabilization is lengthened (10 to 12 min) over that of the low-rate filter (about 1 or 2 min). Recirculation also provides a method of diluting the B.O.D. of the filter influent and aids the total B.O.D. removal. In addition, greater hydraulic penetration is accomplished; therefore, the food load carries farther into the filter.

Other advantages claimed for the high-rate trickling filter are that there are no ponding or fly problems, a constant hydraulic load is provided for the distributors, and there is an opportunity to utilize the excess oxygen present in the recirculated effluent.

Growth Phases Utilized

The relationship of the growth of microorganisms in the high-rate trickling filter to those found in low-rate filters and activated sludge is shown in Fig. 4. The high-rate trickling filter slimes utilize only a portion of the logarithmic growth phase and deal primarily with the declining and endogenous growth phases.

The ratio of food concentration to microorganisms is high in the outside layer of the high-rate trickling filter slimes and near the top of the filter. Thus, at these locations one could expect the microorganisms to experience the logarithmic growth stage.

The inner layers of the slimes and the lower portions of the filter have lower ratios of food concentration to microorganisms and experience the declining growth and endogenous stages. The higher rate of hydraulic loading causes a continuous sloughing and thinner layers of trickling filter slimes. In low-rate trickling filter slimes the thickness of the layers of

ADVERTISING PAGES R327-R330, NOT AVAILABLE
FOR PHOTOGRAPHING.

microorganisms is greater and the activity falls principally into the declining growth and the endogenous growth phases.

These various growth phases in the high-rate and low-rate trickling filter slimes help to explain the different rates of biological activity in the two units. Engineers usually specify that the B.O.D. of the influent to a high-rate trickling filter be less than three times the B.O.D. of the desired settled effluent.[5] Such a limit is reasonable, and if too high a B.O.D. loading is applied to a high-rate trickling filter, the ratio of food concentration to microorganisms will be very high and the activity of these microorganisms will move to the left in Fig. 3, taking in the declining growth phase and a small portion of the logarithmic growth phase, thus yielding microorganisms that have poorer flocculating ability. This limits the degree of B.O.D. removal. In the trickling filter units, "high-rate" seems to mean a high-rate of hydraulic loading, as well as a higher rate of biological activity than in the low-rate trickling filter.

Recirculation Methods for High-Rate Trickling Filters[6]

A number of recirculation methods commonly employed in high-rate trickling filter sewage treatment plants are shown in Fig. 4. This discussion is confined to one-stage units.

The *Bio-filter* is usually shallow and employs recirculation of all or part of the filter discharge back to the detention tank. The filter discharge that is recirculated may be filter effluent, or secondary clarifier content, underflow, or effluent. These Bio-filter recirculation methods are shown in Fig. 4.

The *Aero-filter* process is claimed to provide a low momentary rate of sewage application whereby a high daily capacity for B.O.D. reduction is obtained. Recirculation is used principally during low flow periods. The settled filter effluent is recirculated directly to the filter distributor (Fig. 4.)

The *Accelo-filter* provides direct recirculation of unsettled effluent from the filter to the filter distributor (Fig. 4).

High-Rate Package Plants

The term "package" as applied to sewage treatment refers to the combining of two or more processes into one unit. Thus, one may find package units which combine two or more of the following unit processes:

1. Primary sedimentation.
2. Biological oxidation.
3. Biological flocculation.
4. Final clarification.

Figure 5 is a flow diagram of a package unit employing activated sludge. A flow diagram for a package unit using a trickling filter is shown in Fig. 6.

Various phases of the growth curve may apply to package-type units, as they do for each unit process separately in the conventional plants. Bearing in mind that high-rate sewage treatment means either a high-rate of biological activity or a combination of a high-rate of biological activity and hydraulic loading, it may be possible to have these high-rate principles in a package unit.

In a unit employing activated sludge, the relative amounts of influent B.O.D. to suspended solids can be controlled so as to maintain a high ratio of food concentration to microorganisms. The resulting biological activity in the unit falls into the logarithmic growth phase. Thus, the activated sludge in the unit is principally in the logarithmic growth phase, and a high-rate of assimilation of organics is accomplished. However, the same limitation as to final effluent B.O.D. and B.O.D. removal percentages would be expected as previously discussed; that is, a B.O.D. removal of approximately 60 to 70 per cent.

With package units employing trickling filters the same requirement for high-rate operation apply as presented for high-rate trickling filters. Thus, depending on the operating conditions, high-rate or low-rate principles may be utilized in package plants.

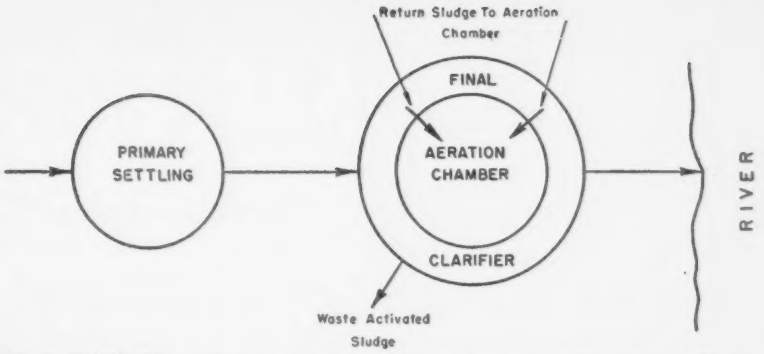

FIG. 5—PACKAGE plant for activated sludge process operates on this flow diagram.

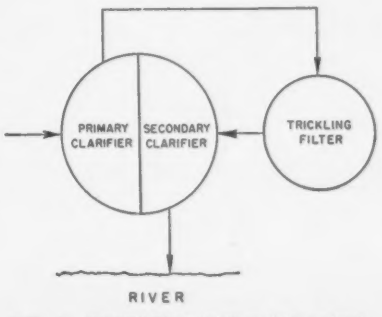

FIG. 6—PACKAGE trickling filter plant has this flow diagram.

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Sewage Filters

by THEODORE JAFFE

Professor of Civil Engineering at Alabama Polytechive Institute, Auburn, Ala.

Treatment of sewage on filter beds has been practiced for many years, the beds usually producing a high quality effluent with a minimum of operation and maintenance.

There are two main classes of filters—sand filters and trickling filters. The trickling filters have been developed in various ways, each having its own name. However, trickling filters are usually classified as (a) low-rate or standard-rate filters, (b) high-rate filters without recirculation, or (c) high-rate recirculating filters. This last type has many flow patterns, as will be shown later.

All of these treatment devices operate on the same basic principles. They are usually preceded by primary sedimentation tanks to remove the solids from the liquid, although some treatment plants have Imhoff tanks for this purpose. In either case, the effluent from these sedimentation units is applied to the filters. All types of trickling filters will be followed by secondary clarifiers, but sand filters do not require secondary sedimentation (Figures 1 and 2).

Bacteria Are All-Important

The treated sewage usually is removed from a trickling filter through an underdrain system, above which rock, slag, gravel or other media is placed. The primary effluent is then sprayed onto the top of the filter bed to percolate down through the media to the underdrains and out to the secondary clarifiers. If recirculation is not desired, the sewage passes through the bed once; if recirculation is required, the sewage is returned to the bed for one or more times, either before or after secondary settling.

The filters clarify and stabilize the applied sewage by aerobic biological action. The media of the beds is home to the bacteria, protozoa, and other microorganisms. The organic matter in the sewage is food; air is supplied either by dissolved oxygen in the sewage, sucked in as the sewage percolates through the bed, or by air channels from outside the bed through the underdrain system and then through the spaces between the media. In most cases air (oxygen) is available to the bacteria from all three sources.

When the bacteria are supplied with food and oxygen, they will eat up the organic matter (thus reducing the B.O.D.) provided they have sufficient time to do so. This time element is one of the reasons that maximum loadings are set up for filters. If the contact time is too short, the B.O.D. removals will decrease.

Another design and operating criteria is the amount of food that can be applied to a given filter; that is, the organic loading. Too much food in relation to the volume of the filter—and therefore the number of bacteria—will give the bacteria indigestion and B.O.D. removals will decrease. On the other hand, too little food (too low an organic loading) will cause some of the bacteria to die of starvation, thus reducing the filter's efficiency.

In addition to the hydraulic and organic loading criteria, the bacteria must not be fed toxic materials, work best in moderate temperatures, and like to live in a neutral pH range. As can be seen, the bacteria are somewhat fussy. Therefore, why is there so much concern about them? The answer is simple—they are the workers at the treatment plant. All the operators do is keep the bacteria happy and contented by adjusting their environment. The plant operator is really a housekeeper, the bacteria are the important members of the "household." In other words, no bacteria, no treatment—even if there were a hundred operators. This is why the term "filters" is incorrect when applied to these units. The stabilization of the sewage is obtained by biological action, not by filtration.

Conventional Filters

As previously described, and illustrated in Figure 1, a trickling filter plant consists of preliminary treatment devices, primary sedimentation, the

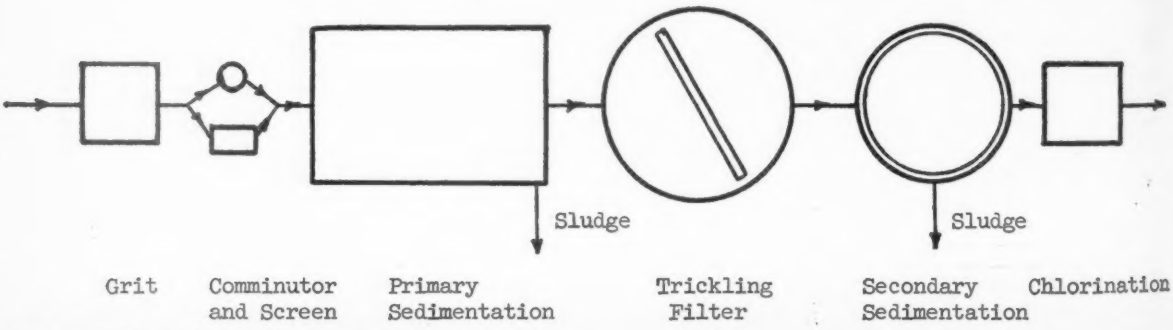

Fig. 1—TYPICAL trickling filter flow-diagram.

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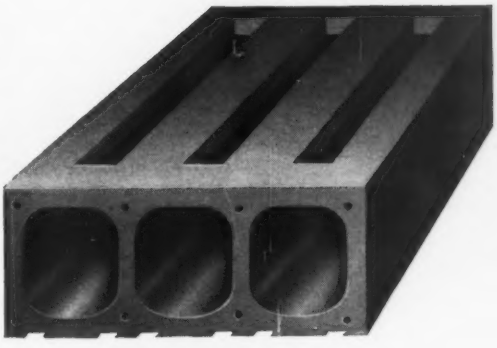
Weight per unit	28 lb.	41 lb.
Weight per sq. yd.	196 lb.	288 lb.
Aeration per sq. ft.	39.3 sq. inch	39.3 sq. inch
Aeration %	27.3%	27.3%
Runoff sq. inch/lin. ft.	30.9 sq. inch	52.4 sq. inch
Runoff %	55.4%	59.3%



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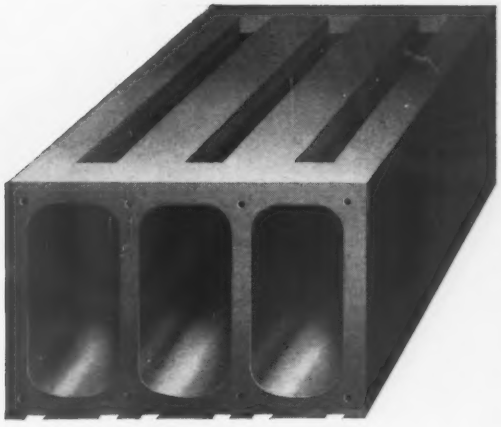
Standard-Rate



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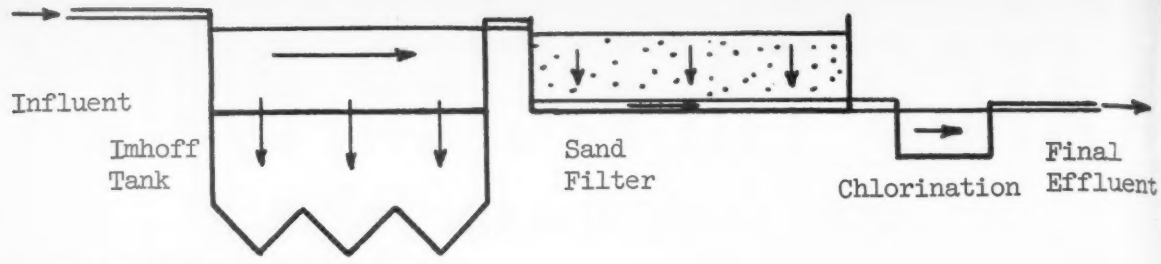

Fig. 2.—FLOW diagram for a sand filter.

filter, secondary sedimentation, chlorination, and sludge treatment and disposal. A high-rate filter without recirculation would be similar to this, but the rate of application would be greater and the filter bed would not be as deep. If recirculation is used, additional piping and pumps are required to return the recirculated flow to the system. Because there are many possible ways of recirculating, no one flow pattern will do. Some of these variations will be shown and discussed later.

To further complicate the picture, filters are sometimes used in series. In this procedure the settled sewage first flows through one filter and then through a second (Figure 3). Here again, many variations are possible. For example, all the sewage may be applied to the first filter and then to the second, or part of the flow put through the first, and then this part plus the remainder of the primary effluent put through the second. Another variation sometimes used in this "stage-filtration" system, is to alternate the flow pattern so that the primary effluent which was first applied to filter number one and then through number two, is applied instead to filter number two first and then back onto number one.

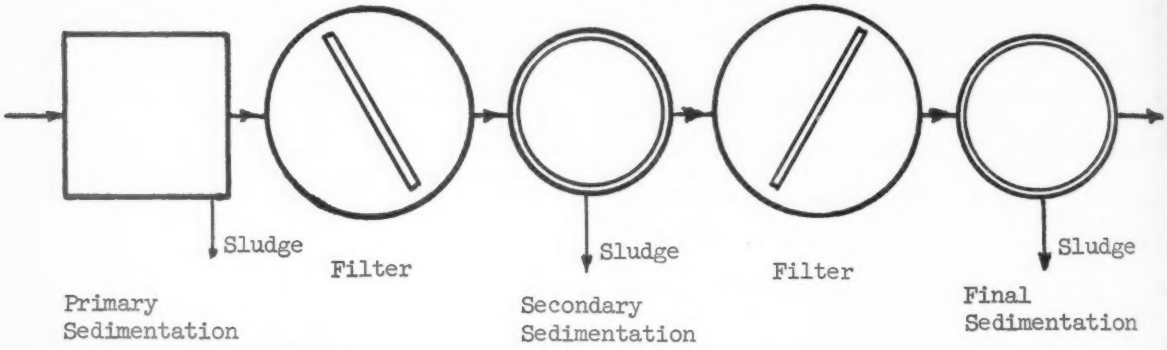

Fig. 3—SERIES operation flow diagram.

Low-Rate vs High-Rate Units

Whether a filter is classified as a low-rate or high-rate unit depends upon two factors—hydraulic or liquid load on the bed, and the organic or B.O.D. load. Both criteria are important for, as previously mentioned, a certain contact time and a certain food supply are both essential for efficient operation. The hydraulic loading is a measure of the contact time, and the organic load is a measure of the food.

Low-rate filters are generally those that have between 1 and 5 mgd applied per acre of filter bed. These units are usually from 6 to 10 feet deep. With good operation they will normally remove more than 85 percent of the B.O.D. of a domestic sewage.

High-rate filters usually operate in the range of 10 to 30 mgd per acre. They are usually shallower in depth, running from 3 to 6 feet deep. Because they are dosed at a higher rate, the efficiency will be lower unless recirculation is used. However, with good design and good operation, very high removals can be obtained even with the greater applied loadings.

The hydraulic loading rates mentioned assume that an average domestic sewage is applied to the filter. On that basis, the organic loading rate (B.O.D.) for a low-rate filter is 1,500 to 7,500 lb of B.O.D. per acre of bed per day; for high-rate operation,

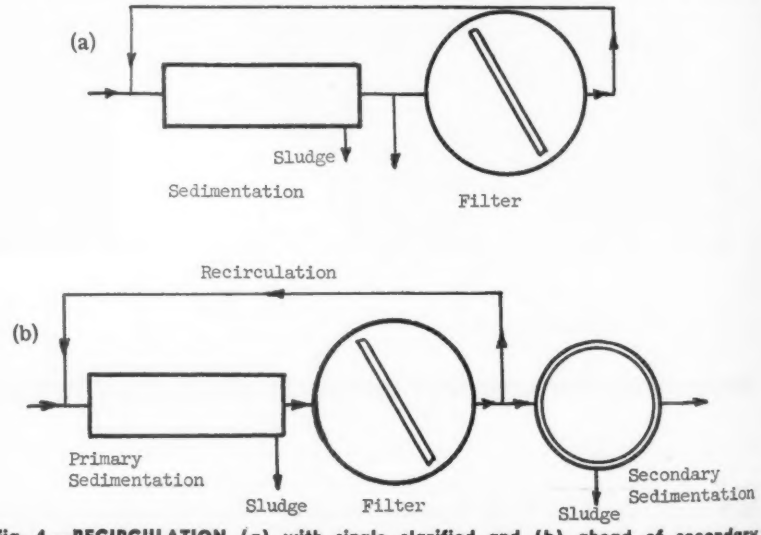

Fig. 4.—RECIRCULATION (a) with single clarified and (b) ahead of secondary sedimentation.

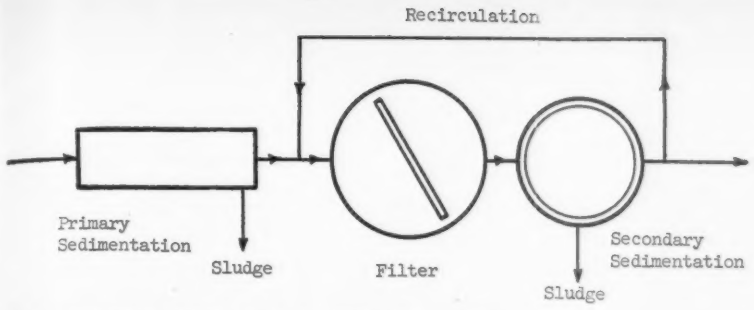

Fig. 5.—RECIRCULATION after secondary sedimentation.

the loadings used are from 10,000 to 45,000 lb of B.O.D. per acre per day.[1]

Incidentally, the subcommittee of the Federation's Committee on Sewage and Industrial Wastes Practice has recommended an entire new set of units for all terms used in sewage works.[2] The foregoing loadings are expressed in the older units, however, so it might be good practice for the reader to convert these to the new, recommended units after reading this article.

So much for conventional trickling filters and their operation. What are some of the variations and developments in filters?

Variations and Developments

Low-rate trickling filters replaced sand filters, historically, because sewage loads—both hydraulic and organic—had increased to the point of lower and lower removals through the sand units. High-rate filters and recirculating filters followed for similar reasons. With the continually increasing demands on treatment works, operators and research workers have continued to seek ways of loading these filters with still greater quantities while retaining high degrees of removal. Most of the results of these experiments have been patented by the various equipment manufacturers and have been given trade-marked names.

Recirculation of a waste through a filter usually will assume one of two basic patterns—recirculation before clarification (Figure 4) or recirculation after clarification (Figure 5). In the first case, the filter effluent to be recirculated is returned to the primary clarifier for sedimentation, the primary effluent (recirculated flow + new waste) going back to the filter. The plant effluent may be picked off at either of two places—between the primary tank and the filter (Figure 4a); or after the secondary clarifier (Figure 4b).

Figure 5 shows the flow diagram for recirculation after secondary sedimentation. The portion to be recirculated is returned to the filter, the remainder of the flow going to chlorination and discharge. In all types of recirculation there naturally must be an effluent so that the volume on the filter does not build up indefinitely. There is one exception—in plants where the raw sewage flow drops to an extremely low amount. This often leads to recirculation of almost all (or all) of the flow so that the filter will not dry and the microbes die. In these cases, the main purpose of recirculating is to keep the filter bed wet. At other times, part of the flow may be recirculated to keep up the hydraulic load on a filter.

Stage filtration may also have many flow patterns. One typical arrangement without recirculation is shown in Figure 3. All of the stage operations are series arrangements and again the returned flow may be diverted before or after sedimentation and returned directly to the first-stage filter, or there may be no recirculation at all. Figure 6 shows one type of series operation with recirculation.

Media Suitability

Recent developments in trickling filters have been in several directions. Attempts have been made to utilize either native materials or new synthetic materials as bed media in place of the customary rock or slag. This approach seeks primarily to reduce the initial cost of filters. Experiments have been under way at the University of Florida for some time to determine the efficiency, suitability, and durability of native Florida materials as filter bed media. A bed of slag was the control against which river gravel, waste pine wood, and limestone were compared. The results of these tests showed that these native materials, costing much less than the conventional slag media, made acceptable substitutes. Another interesting result of these experiments was the observation that good B.O.D. removals had been obtained at both the 2-foot and 4-foot depths, and after further study Furman advocated 4-foot filters for semi-tropical areas.[3,4,5]

Use of an artificial or synthetic media for a trickling filter has been reported by Bryan.[6] This is a plastic material (polystyrene) which is presently fabricated in corrugated sheets and other forms. It has been reported[6] that the biological slimes will attach themselves to the plastic sheets. Several advantages are claimed for this material compared to conventional media—light weight, high void

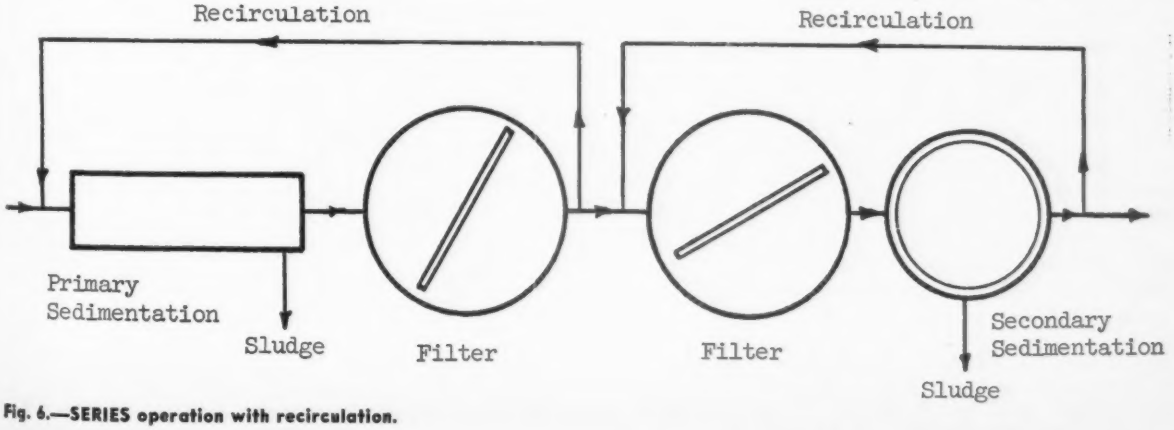

Fig. 6.—SERIES operation with recirculation.

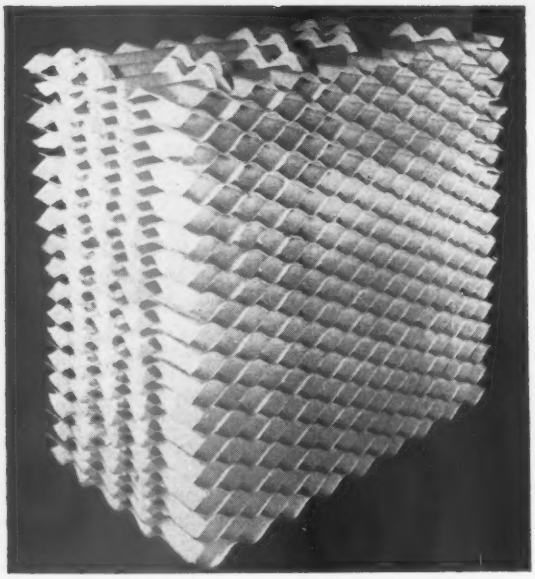

Fig. 7A.—PLASTIC filter bed media now under development.

Fig. 7B.—EXPERIMENTAL tower filter using plastic media.

(Both photos courtesy Dow Chemical Co. which is carrying on experimental development studies with this polystylrene plastic media.)

space ratio, ventilation, and ease of assembly and packing of the filter. Experimental units using this material have generally been in the form of a tower, rather than in the familiar circular shape of the slag or rock filters (Figure 7).

Other Developments

Another direction in which recent research has turned is toward other biological mechanisms or devices. In Germany,[7] designers favor deep filters (10 to 12 feet) in preference to recirculation. To provide adequate ventilation through the filters, the bed has a false bottom below which the outlet and aeration holes are provided. It is claimed that, without recirculation, this filter can reduce the applied B.O.D. of 157 ppm to 14 ppm; a reduction of 91 per cent.

Several investigators have operated tray-type percolating filters arranged as a tower. These consist usually of a series of trays or cells, one above the other, with air spaces between. The sewage is applied at the top and flows down, picking up oxygen as it drops from the higher to the lower tray. Gloyna and Smith[8] reported a 90 percent B.O.D. reduction after settling. Bernhart[9] reported on using pre-cast concrete cells in tiers.

To improve the efficiency (using high loadings) these tower arrangements have also been investigated using forced air. Schulz[10] reports using an experimental tower filter with forced ventilation and without artificial aeration. When natural ventilation was used, he obtained a 91 percent reduction in B.O.D. at about 4.5 times the normal loading.

Another experimental unit of this type is that reported by Ingram[11] and shown in Figure 8. This also employed artificial aeration and he concluded that: "A standard-rate filter which would effect the same amount of removal would require 24 times the area and contain 8 times the media volume. A high-rate filter would require 14 times the area and 4 times the volume".[12] During the course of these studies it seemed that "no reliable limiting relation or removal of B.O.D. to either organic or hydraulic load was found".[12]

This unit (Figure 8) was sealed except at the top. After settling, the sewage was pumped to the top of each

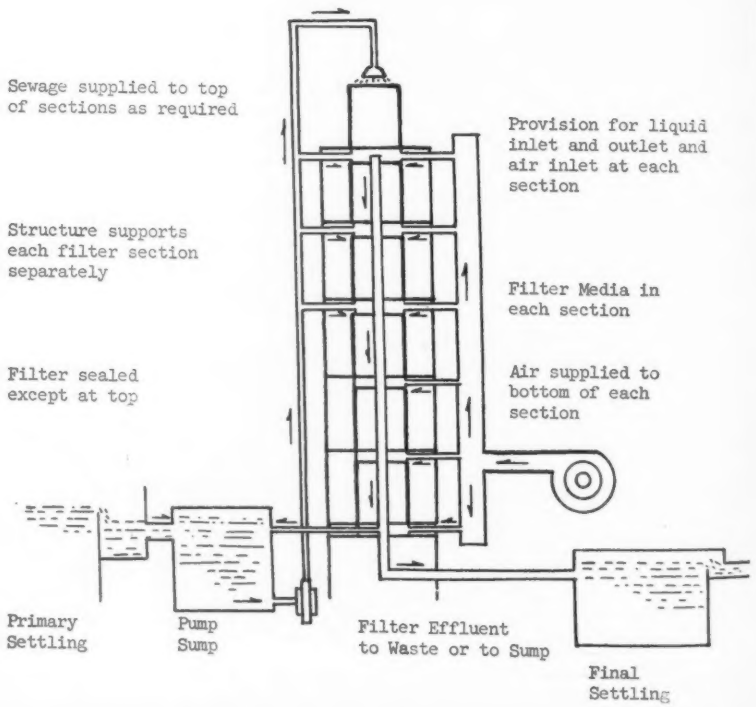
Sewage supplied to top of sections as required
Structure supports each filter section separately
Filter sealed except at top
Provision for liquid inlet and outlet and air inlet at each section
Filter Media in each section
Air supplied to bottom of each section
Primary Settling
Pump Sump
Filter Effluent to Waste or to Sump
Final Settling

Fig. 8.—DIAGRAM of controlled filtration (after Ingram).

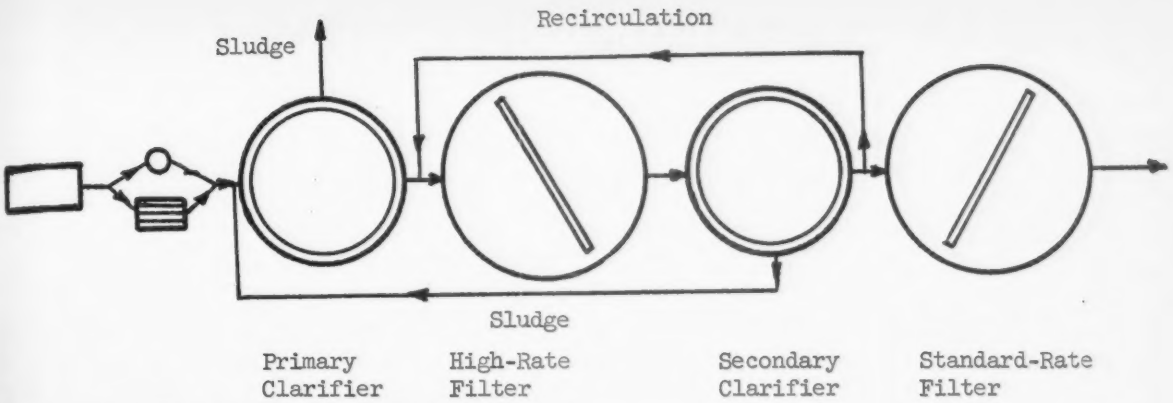

Fig. 9.—HIGH-RATE recirculation followed by standard-rate filter.

of the six sections of the tower. The sewage flowed down through the filter stone in each section to the final settling tank. Air was forced into the bottom of each section. Part of the sectional effluent could be returned to the primary effluent pump sump. For part of this study, all the sewage was applied to the top of the tower; for other study phases, sewage was applied to the sections.

Where sewages having high B.O.D. have been encountered, as in industrial wastes, or where high quality effluents are required for a domestic sewage for only part of a year (for example, summer time with low stream flows, or for recreational purposes), trickling filters have been used in series with other types of secondary treatment. Various schemes have been utilized — standard-rate filters followed by sand filters or activated sludge; standard-rate filters followed by high-rate filters, etc. Sometimes it is more feasible to build the first unit now, and add on the second when the community grows, more financing is available, or for other reasons. Figures 9 and 10 show two of these arrangements currently operating in Alabama. In these series operations, the first filter may serve several purposes—it may take up shock loads which would make the activated sludge operation difficult, or it may iron out the effects of an industrial waste discharged at intervals. At any rate, simpler operation, higher loadings, smaller plants, and better removals are usually the objectives of these systems.

The next article in this series will be concerned with the effects of industrial wastes on sewage plant operation. Many excellent suggestions have been reported by operators who have had these problems and all operators may well benefit by these solutions to exasperating situations.

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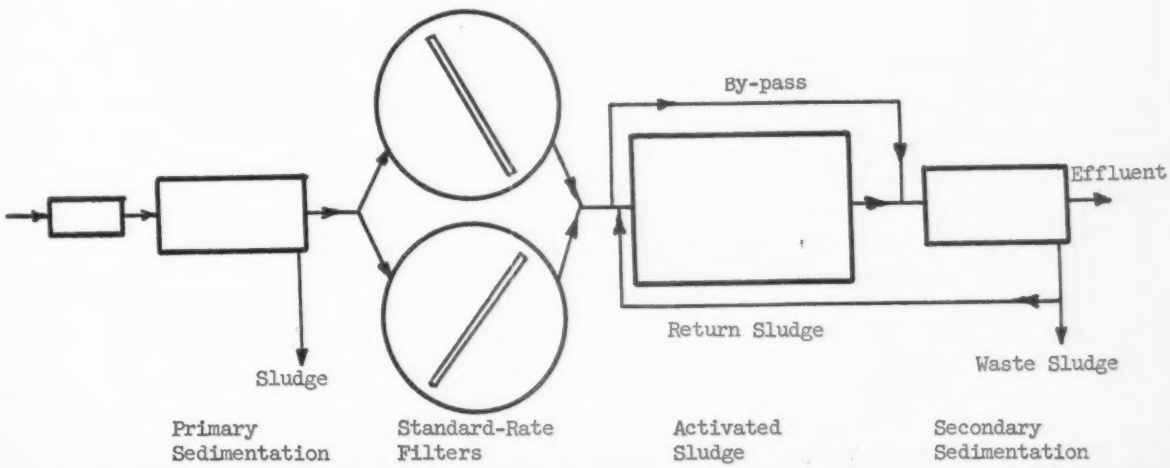

Fig. 10.—STANDARD-RATE filters followed by activated sludge.

PRIMARY CLARIFIER OPERATING GUIDE*

by ROBERT E. LEAVER

Senior Public Health Engineer, Washington State Department of Health, Seattle, Wash.

TABLE I
Symptoms and Remedies for Primary Clarifiers

Settleable Solids, Effluent (ml/l)	Dissolved Oxygen (ppm) Infl.	Effl.	Physical Condition	Probable Cause of Condition	Possible Remedy*
Trace—0.3	>2.0	>2.0	Excellent	—	—
Trace—0.3	>2.0	2.0-0.1	Fair	Warm or strong sewage	1,2,3
Trace—0.3	>2.0	None	Unsat.	Warm or strong sewage	1,2,3
Trace—0.3	2.0-0.1	>2.0	Good	Cold or weak sewage	—
Trace—0.3	2.0-0.1	2.0-0.1	Poor	Stale raw sewage	1
Trace—0.3	2.0-0.1	None	Unsat.	Warm stale strong sewage	1,2,3
Trace—0.3	None	>2.0	Good	Septic cold or weak sewage	4,5,6
Trace—0.3	None	2.0-0.1	Poor	Septic sewage	2,4,5,6
Trace—0.3	None	None	Very bad	Warm strong septic sewage	1,2,3,4,5,6
>0.3	>2.0	>2.0	Poor	Too much sewage	7
>0.3	>2.0	2.0-0.1	Poor	Too much strong sewage	7,2,3
>0.3	>2.0	None	Unsat.	Overloaded (hydraulically and organically)	2,3
>0.3	2.0-0.1	2.0	Poor	Too much stale cold sewage	7
>0.3	2.1-0.1	2.1-0.1	Poor	Too much stale sewage	2,7
>0.3	2.1-0.1	None	Unsat.	Too much stale or warm strong sewage	2,3
>0.3	None	>2.0	Fair	Too much septic cold sewage	7,4,5,6
>0.3	None	2.1-0.1	Unsat.	Too much septic sewage	7,2,4,5,6
>0.3	None	None	Terrible	Many reasons	2,3,4,5,6

Regardless of the elaborateness of the primary clarifier, operational problems arise that only the operator can cure. Since solids removal is basic to most of the other treatment operations, time spent in remedying these problems usually pays large dividends.

Table I lists some common operating conditions and possible remedies. In attempting to find the cause of the condition only physical appearance, settleable solids, and dissolved oxygen information are used. Equipment for determining settleable solids and dissolved oxygen content is very inexpensive and within the means of any plant. One or more of the remedies in Table II may help correct conditions noted in Table I. The correct remedy must often be determined by the process of elimination—a method familiar to all operators.

TABLE 2
Operating Remedies

No.	Remedy
1	Increase flow to primary clarifier.
2	Prechlorinate so that no chlorine residual is in the effluent.
3	Aerate or add recirculated liquid high in dissolved oxygen.
4	Add upsewer chlorination so that no chlorine residual is present in plant influent.
5	Flush sewers routinely.
6	Decrease retention time in lift station.
7	Decrease flow to primary clarifier.

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ACTIVATED SLUDGE

THE ACTIVATED sludge process of secondary treatment differs from trickling filter operation in that precipitation and oxidation takes place on the extensive surfaces of active biological flocs which are maintained in suspension in the sewage being treated. These biological flocs, which are termed, "activated sludge," are moved freely through the liquid, either by mechanical mixing or by agitation with air bubbles. This agitation brings air in contact with ever changing surfaces of water, and dissolves oxygen in the liquid, thus becoming available to the organisms in the free floating activated sludge floc.

As organic matter is adsorbed and decomposed on the floc, the floc grows in quantity and volume; therefore some of the sludge must be wasted. Following the aeration period, the mixed liquor of sludge and treated sewage passes to a secondary clarifier, where the sludge settles. A portion of this settled sludge is returned to the inlet end of the aeration units where settled sewage is also added and excess sludge is pumped to the sludge disposal process.

Plant Characteristics

Activated sludge plants require relatively small land area and construction costs are lower than for trickling filters. Operation costs, however, are higher than those of trickling filters because of the power requirements for aeration. Tanks for aeration are usually 15 ft deep and long and as wide enough to produce the required aeration time.

Diffused air may be added from porous plates or tubes, impingement aerators, jet aerators, fabric diffusers, etc. The air is introduced in such a manner as to create a spiral flow of sewage through the tank. Air blowers and air filters are required. In another method of aeration air enters from a central rotating shaft near the bottom of a tank and is dispersed by a rotating paddle device ("Cavitator").

Mechanical aerators are either paddle or vertical draft tube. In the former, a paddle wheel or brush revolves on a horizontal axis and is partly submerged in the sewage. In the latter, sewage is drawn up (or down) through a central tube by means of a revolving impeller, which provides both agitation and aeration.

Operation

Activated sludge plants generally produce better results than trickling filters but require more attention and control. There should be some dissolved oxygen present in the influent end of the aeration tanks and at least 2 ppm in the effluent from the aeration tanks.

Aeration periods vary from 3 to 12 hours (common 4 to 6 hr) depending on the installation, B.O.D. load, etc. Air consumption varies from 0.35 to 1.7 cu ft per gal of sewage (common 0.7 to 1.2). Solids carried in the aeration tank (termed mixed liquor solids) vary from 700 to 4000 ppm (normal 1000-2000 ppm). On the average, activated sludge plants may be expected to produce an effluent (after final settling) with 10 to 20 ppm of suspended solids and 8 to 18 ppm of B.O.D. The stronger the sewage load, the higher the removal of solids and B.O.D.

The quantity of excess sludge removed is equal to 1 to 1½ per cent of the volume of sewage treated. The volume of sludge returned to the aeration tanks is from 15 to 40 per cent of the final clarifier sludge, and will depend on concentration of sludge solids in the final sludge and desired concentration of suspended solids in the aeration tank.

One of the problems is sludge bulking, wherein the sludge fails to settle properly in the final tank and goes out over the weir. Bulking may be controlled by chlorination and by controlling the sludge index (weight of sludge per unit volume) plus tests on the activity of the sludge (i.e., its oxygen consumption per unit weight per unit time). Most mechanical aeration plants are relatively small installations.

Modifications of Process

Tapered aeration is a method of controlling the input of air (oxygen) at various points in the tank (more air being added at the influent end) so that the aeration rate is tapered or regulated by determining the "Nordell Number" (quantity of oxygen utilized in ppm per hour by weight).

Step Aeration is a modification, whereby the sewage is introduced at multiple points throughout the course of the flow of the returned sludge through the aeration tanks. Other terms for this method are "distributed loading," "multiple-point dosing," and "incremental feeding."

High Rate Activated Sludge Treatment, or "modified aeration," consists of short aeration periods and relatively small amounts of return solids. This method is intermediate between primary sedimentation and high rate single stage trickling filters or activated sludge. The degree of treatment is controlled by the air supply, aeration period, and amount of returned solids (usually 600 to 900 ppm). Low air supply, small tank capacity and dense excess sludge are possible.

Proprietary Processes

Bio-chemical Process is the trade name applied to the Guggenheim process, which employs the addition of a coagulant (iron salts or alum) in the activated sludge process, the coagulant being added together with the return sludge to the aeration tank.

P.F.T.-Kraus Process, or the "digester liquor nitrification process", operates on the principle of correcting the carbon-nitrogen ratio in the food supply for the micro-organisms. Digester liquor or digested sludge (or a combination) is mixed with return activated sludge and this mixture added to one or more aeration tank units. The high ammonia content of the digester liquor or sludge is oxidized to nitrites and nitrates and the density of the sludge is increased in proportion to the amount present of digested sludge of higher specific gravity.

Oxidized Sludge Process (Mallory process) was a term given to what was essentially a control process for the activated sludge system.

Patented Process and Equipment includes the "Aerator-Clarifier" (Chicago Pump Co.); "Dorrco Aerator-Clarifier" (Dorr Co.); "Aerifier" (Yeomans Bros.); "Currie Claraetor (Dorr Co.); "Process Oxidator" (P.F.T. and Process Engrs.), all of which combine mechanical aeration with a clarifier in one unit.

Other combination processes include "Bio-activation," a combined high rate trickling filter and activated sludge (American Well Works); "Aero-Accelator" (Infilco, Inc.) in which a high rate activated slurry biological treatment is effected; "Accelo-Biox" process (Infilco, Inc.) which involves the direct recirculation of mixed liquor through the aeration tank of an activated sludge plant, and "Biosorption" process (Infilco, Inc.) in which raw sewage is mixed with activated sludge and settled, the sludge then being aerated.

"Bio-precipitation" employs oxygen (95 per cent pure) for oxidation by an active biological sludge. The process employs counter current flow of sewage.

Activated Sludge

by DON E. BLOODGOOD

Professor of Sanitary Engineering, Purdue Univ., Lafayette, Ind.

EDWARDS SAID in 1935[1] that the mechanism of the activated sludge process probably involves physico-chemical, enzymic, biological and bio-chemical reactions and that at some time every one of these phenomena has been used to explain the entire process, but it is generally agreed that each plays a part in the operation and that a combination of all is essential for satisfactory purification.

The Process

Parsons and Wilson[2] believe that the reactions mentioned by Edwards bring about clarification, reactivation of the sludge and nitrification. Even though the process has been divided into stages it is actually very difficult to separate the various reactions because they are all so interrelated.

For many years there have been arguments about whether the activated sludge process is chemical or biological. It is a certainty that biological life is essential for the completion of the process but it is certainly debatable whether the processes preparing food for the microorganisms are chemical or biological.

In the clarification by activated sludge the carbonaceous and nitrogenous organic materials, whether they are in suspension, colloidal or in solution, are removed by coagulation and adsorption. The clarification takes place in a very short period of time. This rapidity of action can be demonstrated by placing about 100 ml of return sludge containing 10,000 ppm. in a 500 ml cylinder, adding 400 ml of sewage to the sludge, inverting the cylinder about ten times and then allowing the sludge to settle. If the activated sludge is in good condition the sewage will be reasonably well clarified. Bender has used the clarifying power of activated sludge to advantage when he has exposed waste activated sludge from the Indianapolis plant to a large quantity of sewage, thereby clarifying the sewage but with no reactivation of the sludge.

In the clarification there is very little if any decomposition of the materials removed from the liquid. It is reasonable to believe that in order to have the clarification process carried on there must be some rejuvenation of the sludge. The rejuvenation or reactivation is believed to be accomplished by the activity of microorganisms.

The biological reactivation is carried on by a mixture of microorganisms. Ruchhoft, Butterfield, McNamee and Wattie[3] have shown that the clarification and reactivation can be carried out with pure cultures of bacteria isolated from good activated sludge. The fundamental characteristic of the organisms isolated and used to demonstrate clarification and reactivation were of the zooglea-forming group. Theriault[4] believes that the reactivation process and the clarification are closely allied and that the gelatinous matrix behaves as a base exchanging substance in the clarification and that it is regenerated by the bacteria that produce it. Hoover, Jasewicz and Porges[5] indicate that in the reactivation of the sludge the stored food is utilized.

activated sludge, considerable atten-

In the earlier years of the use of tion was given to nitrification and the appearance of nitrites and nitrates in the effluent. In more recent years less attention has been given to the actual nitrification taking place. It is true that the presence of nitrates in the concentration of 4 to 12 ppm. in the effluent indicates a highly oxidized sludge.

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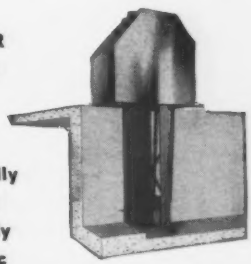

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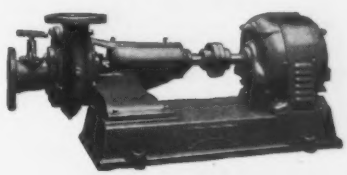

Fig. 5500 Sludge Pump

SLUDGE REMOVAL

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SLUDGE AND SEWAGE PUMPS—Fig. 5500 cutting type primary sludge pump. Fig. 5100 enclosed impeller type raw sewage pumps. Fig. 5600 single vane impeller type sewage pumps. Fig. 8400 recirculation pumps. This line of horizontal and vertical pumps ranges in size from 3" to 18" inclusive, in capacity from 40 to 10,000 GPM, and in head from 5' to 85'.

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Weston and Eckenfelder[6] have stated that it is theorized that: (a) organic matter is removed from solution by reaction with enzymes that bring about coagulation; (b) organic matter is oxidized; (c) bacteria cells are produced from organic matter removed; and (d) cell material is oxidized.

In the cell material oxidation there is certainly an oxidation of protein materials with the production of nitrites and nitrates. It therefore can be reasonably deduced that the presence of nitrates in an activated sludge plant effluent means that a stabilizing of bacterial cell population is taking place or that all of the nitrogenous materials in the sewage are not being converted into living cell material. Hoover and Porges[7] call the oxidation of bacterial cell material "endogenous respiration" and say that it is analagous to the basal metabolism in humans.

The biochemistry of the activated sludge process is complex and no doubt is not yet thoroughly understood but certain fundamental concepts are well established.

Oxidation Rates

The activated sludge process was developed with the understanding that it utilized aerobic microorganisms to do the work required.

In the wet combustion taking place in the activated sludge process, quantities of carbon dioxide are produced. In fact, carbon dioxide is the main end product of aerobic decomposition.

Heukelekian and Ingols[8] as well as many others have studied the oxidation rate of activated sludge. Some of the workers have measured the carbon dioxide produced and others have measured the amount of oxygen utilized. Heukelekian and Ingols found that the highest rates of carbon dioxide production occur during the initial period of aeration of a sewage with an activated suldge. They showed that the quantity of carbon dioxide produced was in direct proportion to the strength of the sewage being treated by activated suldge.

Kessler and Nichols[9] measured the amount of oxygen used in the oxidation of sewage with activated sludge. This earlier work also showed that there is a higher oxidation rate in the earlier stages of the activated sludge process. They showed that the oxygen requirements at the beginning of an aeration tank are five to six times greater than they are at the end of the aeration tank .

The studies reported by the writer[10] [11] showed that there is considerably more oxygen utilized at the beginning of the aeration in an activated sludge plant.

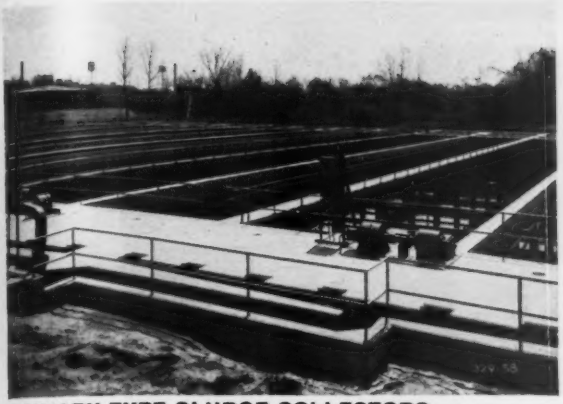
MECHANICAL aeration tanks—Hartford City, Ind.

Kessler[9] reported that the oxygen requirement at the beginning of an aerator might be as high as 137 ppm per hour and after 2.5 hours of aeration it might be down to a demand of 28 ppm. Other test data presented by him showed that the demand in the earlier stages of aeration might be only 20 ppm per hour, decreasing to 5 ppm per hour after 17+ hours of aeration.

In utilizing mixed liquor solids of 5000 ppm in the apparatus used in the writer's studies[10] the total oxygen requirement was as high as 190 ppm of oxygen per hour at the beginning of aeration. Tests over a long period of time showed that the demand for oxygen after the required aeration period in an aerator should be between 20 and 70 ppm per hour. These data do show the need for sup-

Photo courtesy Dorr-Oliver Corp.

ACTIVATED sludge plant-Canton, Ohio



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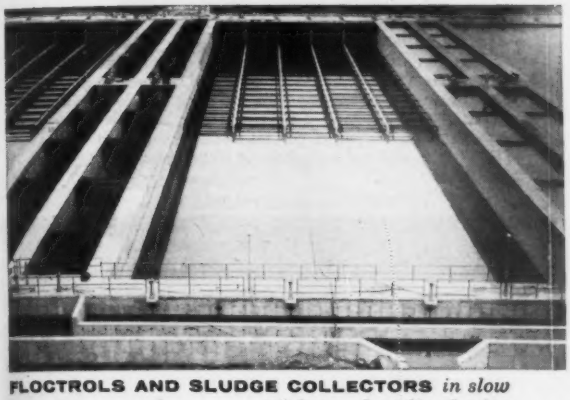

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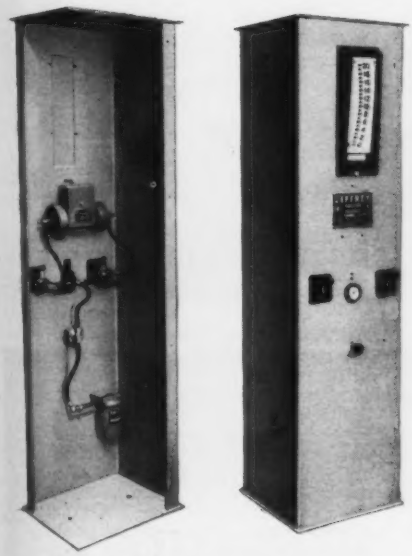

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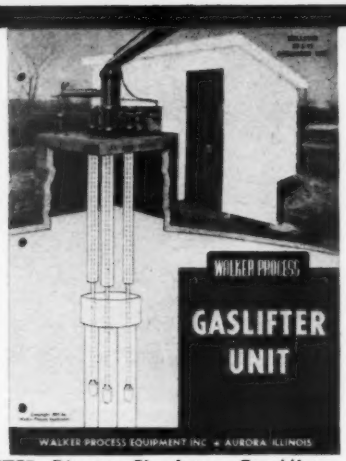

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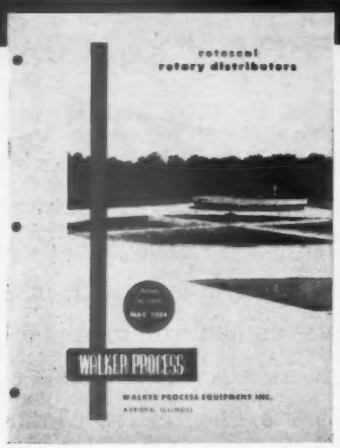

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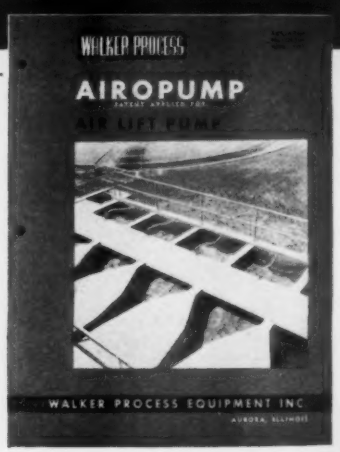

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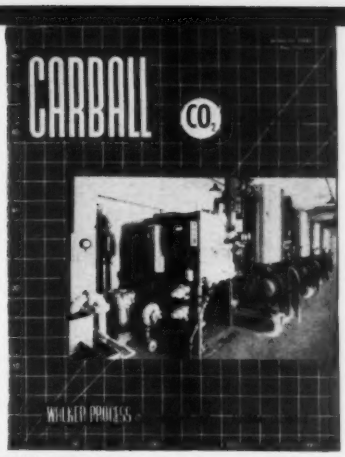

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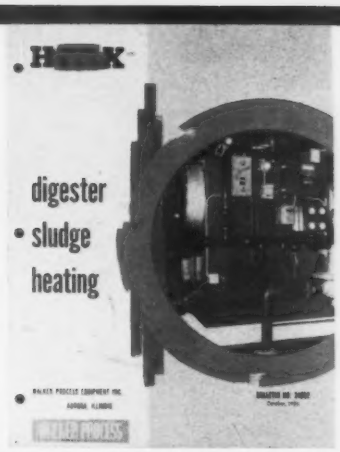

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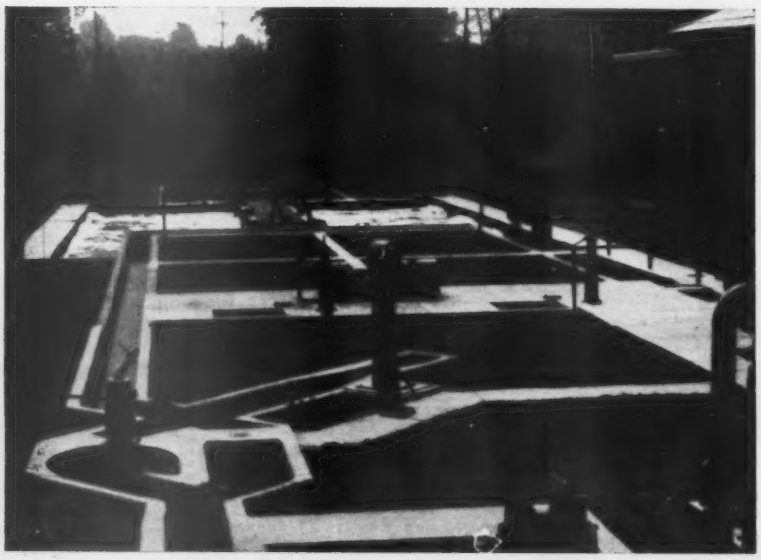
DIFFUSED air aeration—Hammond, Ind.

plying greater quantities of air at the beginning of an aeration tank. "Tapered aeration" is the term that has been applied where there has been an attempt to apply air at the demand rate in the aeration tank.

The actual demand of activated sludge or oxygen does not give the plant operator a way to determine the amount of air that he should apply to an aerator. He must depend in most cases on the amount of oxygen remaining dissolved in the liquid to guide him in the regulation of the air applied. A general rule applied in some operation standards says that the dissolved oxygen in the liquid at the end of an aerator should not be below 2.5 ppm. This should not be interpreted to mean that this concentration is needed because it has been said that the organisms will get their required oxygen if there is any dissolved oxygen present. It is most difficult with the high oxygen requirement at the beginning of an aerator to make a dissolved oxygen determination on the liquid at that point, therefore it is practical to run the dissolved oxygen on the liquid at the end of the aeration tank where the demand rate is much less. Finding 2.5 ppm of oxygen at the end of the aeration tank means that if this is an appreciable amount of dissolved oxygen at the end of aeration then it is hoped that there will be the amount needed at the beginning of the aerator. Usually the air requirement is 400 to 1000 cubic feet per pound of B.O.D. removed.



ACTIVATED sludge plant—Greencastle, Ind.

Mixed Liquor Solids

The concentration of mixed liquor maintained has varied from plant to plant. In the mechanical aeration units it has usually been found impossible to maintain concentrations of much over 1200 ppm while in the diffused air systems mixed liquor solids as high as 6000 ppm have been maintained.

It has been concluded that there is no one fixed concentration of mixed liquor solids that is universally satisfactory in all plants. Back in the 1930's there was a trend to carry lower concentrations of mixed liquor solids; in recent years the trend has been to carry them above the once fixed figure of 2500 ppm.

Heukelekian[12] has said the higher the concentration of mixed liquor solids, the lower will be the rate of accumulation of solids when treating a particular sewage. This seems reasonable because the higher the mixed liquor solids, the longer will be the retention of solids in the system. The period of retention of solids in the system is sometimes described as sludge age. The age of sludge in a particular plant governs the volatile solids content of the mixed liquor. Usually the higher the ash content of the mixed liquor solids the greater has been the oxidation of the volatile solids.

It is believed that mixed liquor solids with an ash content of 35 to 40 percent can be expected to settle very well. The settling characteristic of a mixed liquor is easily determined by the sludge index test. Sludge index is defined as the volume of settled sludge occupied by one gram of solids after settling 60 minutes. The reciprocal of the sludge index times 1,000,000 will give the concentration of the settled sludge in ppm. It can be said that the return sludge concentration in the plant should never be greater than the concentration as calculated from the sludge index.

It is necessary to keep activated sludge solids well aerated and in order to do this they must not be retained for more than an hour in the settling tank. A check on the balanced condition of the mixed liquor solids and the return sludge solids can be made with the simple formula:

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$$(a + b)x = by$$

where a = sewage flow in mgd
b = return sludge flow in mgd
x = mixed liquor solids concentration in ppm
y = return sludge solids concentration in ppm

Substituting values obtained from analyses and meter readings will make it possible to determine whether the solids and flows are in balance. If the equation does not balance then a value for return sludge concentration computed from the sludge index should be substituted in the formula and then it must be solved for return sludge flow. This return sludge flow computed in this manner is the minimum flow that can be utilized to keep the solids in the system in balance.

B.O.D. Loadings

The present day basis of design for aeration tanks built in some parts of the country is that there must be 1000 cubic feet of aeration tank for every 33.3 lb of B.O.D. in the aerator influent. There are some plants in operation today[13] where 2 to 3 times this loading is being successfully handled. It is the writer's opinion that these plants are being skillfully handled and that there is no limit on the quantity of air being used, if it is observed that the air is actually needed. When the high loadings are practiced and exceptionally well purified effluents are obtained the concentration of mixed liquor solids is proportionally higher.

Temperature Effects

Wisely[14] has written that hot weather temperatures do not seriously affect the activated sludge process. The writer has found from his work in the Indianapolis plant[15] that the detention time in an aerator could be reduced from 11 hours at 14° C. to 7.8 hours at 26° C. This also means that a larger quantity of B.O.D. can be oxidized in warmer weather than can be in the months when the sewage is cooler.

Sawyer and Rohlich[16] found that the equation $y = 0.71\ x^{1.54}$, in which y is the relative activity in per cent based on the value of 25° C. taken as 100 per cent and x is the temperature in degrees Centigrade, has been found to apply in general to the influence of temperature on the rate of activated sludge oxidation. The Rohlich equation says that the activity is 45 per cent less at 15° C. than it is at 25° C.

Waste Sludge

The amount of sludge solids that must be wasted each day from a plant depends upon the pounds of volatile mixed liquor solids in the plant and the pounds of B.O.D. received each day. Heukelekian, et al.,[12] have developed the formula:

$$A = -0.055\ S + 0.5\ B$$

in which A = the pounds of volatile solids accumulated per day, S = the pounds of volatile mixed liquor suspended and B = the pounds of B.O.D. fed per day. It is apparent from this equation that the greater the concentration of volatile solids in the mixed liquor the less will be the poundage of volatiles that will have to be wasted, providing the B.O.D. loading remains the same.

SMALL activated sludge plant—Culver, Ind.

Summary

1. Activated sludge functions as a purifying process utilizing clarification, reactivation, and oxidation processes.

2. The demand of mixed liquor solids for oxygen is greater shortly after being fed with sewage.

3. The settling characteristic of mixed liquor determines the amount of return sludge that must be pumped.

4. The B.O.D. loading that a plant can handle depends to a great extent on the amount of air that can be supplied and the concentration of mixed liquor solids.

5. Temperatures of the liquid in the aeration tank can greatly influence the amount of organic matter that can be removed and oxidized in the activated sludge process.

6. The quantity of waste sludge that must be disposed of each day depends upon the mixed liquor concentration and the B.O.D. load going to the aeration tanks.

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Chlorination of Wastewater

by EDMUND J. LAUBUSCH

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The year 1957 marked the 50th anniversary of the first domestic application of sewage chlorination on a plant scale at Red Bank, N. J. As in the case of water treatment technology, impetus to its adoption and development, principally for disinfection of polluted wastes and for odor control, came with the commercial availability of compressed chlorine gas in 1909, and of proprietary chlorine feed equipment in 1912-1913.

The use of chlorine for purposes other than waste disinfection and odor control developed only many years later. While its use for the former still constitutes its most important application, as an adjunct to primary and secondary waste treatment processes the benefits of chlorine are becoming increasingly apparent (See Fig. I-1 in Part I).

Although progress in the use of chlorine at sanitary and industrial waste treatment facilities has been steady (see Figs. II-1, II-2), the development pattern in not nearly comparable with that pertaining to water treatment. Now that there is strong public sentiment in favor of water resources conservation and pollution abatement, established and new uses of chlorine may be expected to become more widespread.

Chlorination Theory

The initial reactions that occur when chlorine is added to sewage or industrial wastes may be considered to be essentially the same as those that occur when chlorine is added to water. (See Part I for a more detailed discussion of this subject.) If pH levels are below 3.0 chlorine may be present momentarily in the molecular state. At normal pH levels encountered, however, it exists first as free available chlorine ($HOCl$, OCl^-) and, subsequently, in various combined forms. As in water, but to a much greater degree, free chlorine reacts immediately with a variety of oxidizable and chlorine-absorbing solids and gases in sewage and other wastes.

The amount of chlorine required to carry oxidation and chloro-addition reactions to equilibrium at any given time interval depends on the concentration of the oxidizable and chlorine-absorbing components present. Until that time is reached which is necessary to carry all such reactions to completion, the amount of chlorine consumed will increase with time. Beyond this point chlorine will exist almost entirely in the free available form and will not be consumed.

The intensity with which chlorine enters chemical reactions is measured by its oxidation potential.

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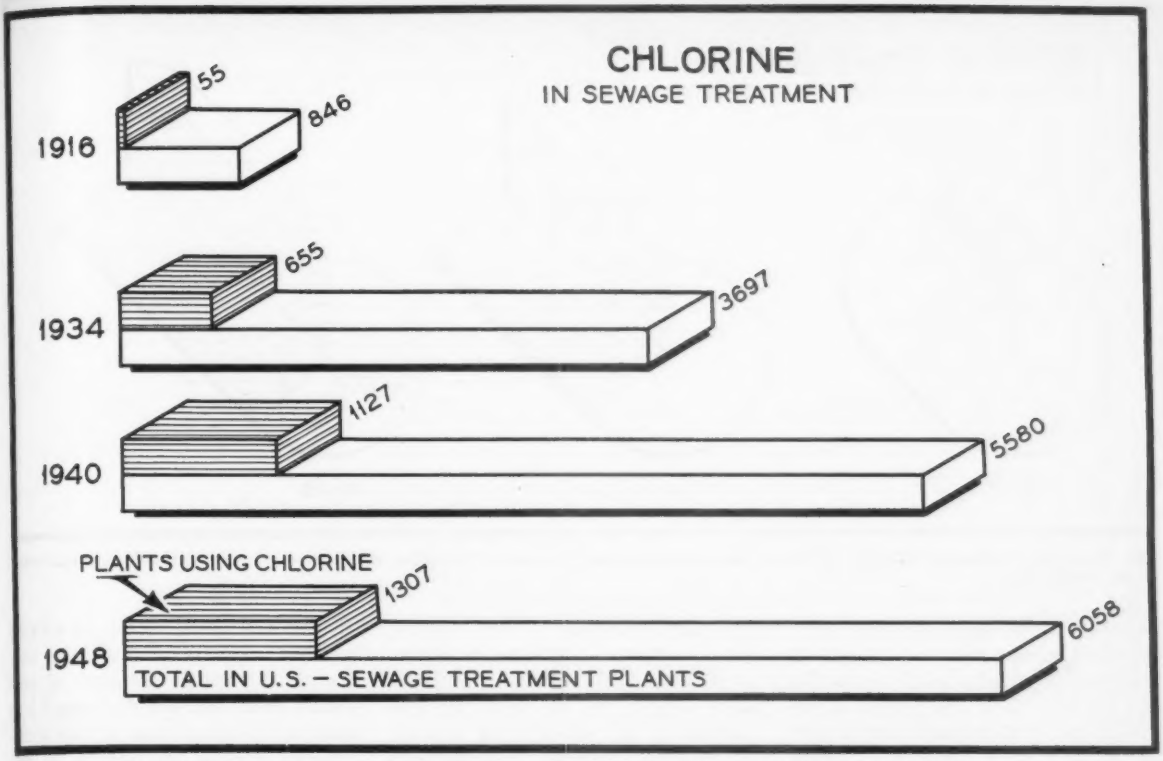

FIG. 11—1. DEVELOPMENT of the use of chlorine in sewage treatment in the United States: 1916-1948.[4,5]

Chloramines formed by the reaction of chlorine and ammonia, and organic chloramines formed by the reaction of chlorine with complex, nitrogen-containing amino acid and protein compounds, have a lower oxidation potential than free chlorine. They are, however, still available for chemical reactions and for disinfection.

Waste Water Constituents

Among the important variable constituents of sewage and industrial wastes that affect chlorination processes are:

Alkalinity
Dissolved gases (including ammonia)
Organic substances (settleable, non-settleable and soluble)
Oxygen demand
Bacteria and other organisms

Alkalinity: The activity of chlorine dissolved in sewage is dependent on the pH. An increase in alkalinity results in the acceleration, and a decrease results in the reduction of both the rate and extent of these reactions. The concentration and form (a function of pH) in which chlorine exists, as well as the concentration and form of oxidizable substances, control the mechanism of the reactions and the end products formed. With some compounds, oxidation reactions proceed only slowly even though the pH, temperature, concentration of reacting substances, and other influencing factors are at optimum levels; in such cases, an appreciable amount of time must be provided to reach equilibrium.

The addition of chlorine to waste water reduces the alkalinity by from 0.7 mg/L to 1.4 mg/L per part of chlorine, depending on the degree of ionization of the hypochlorous acid and the manner in which the chlorine is consumed.

Dissolved Gases: Chlorine reacts with dissolved hydrogen sulfide, a decomposition product of unstable organic components of sanitary wastes. This gas exerts a chlorine demand and reduces the oxidation potential of chlorine.

As noted previously, chloramines formed by the reaction of chlorine and ammonia are lower than free chlorine forms in oxidizing capacity. Similarly, many organic chloramines and chlorine substitutes or derivations of organic nitrogenous compounds do possess disinfecting potentials, but they are of much lower magnitude than those of free chlorine and mono- or dichloramine forms.

Organic Substances: Unstable organic substances normal to sewage and other wastes comprise the bulk of settleable and (especially) non-settleable suspended solids. The removal of settleable organic solids along with stable inorganic materials (sand, grit, etc.) usually presents no special operational problems although they do exert a substantial chlorine demand until separation is accomplished. The removal of colloidal solids, particularly those that are organic, presents treatment complications. Like proteins and amino acids, many of these exhibit a distinct affinity to chlorine and exert a very substantial chlorine demand in the process of chlorine absorption and formation of chlorine-addition products.

Oxygen Demand: The increased oxidation potential of chlorinated sewage and industrial wastes reduces the biological oxygen demand and the putrescibility of the waste. An average 5-day BOD reduction of about 2 mg/L occurs for each part of chlorine added to domestic sewage.

It has been estimated that when sufficient chlorine is added to sewage to carry the oxidation reaction to an equilibrium in a 10-min reaction period, the non-settleable solids (principally unstable organics, but also

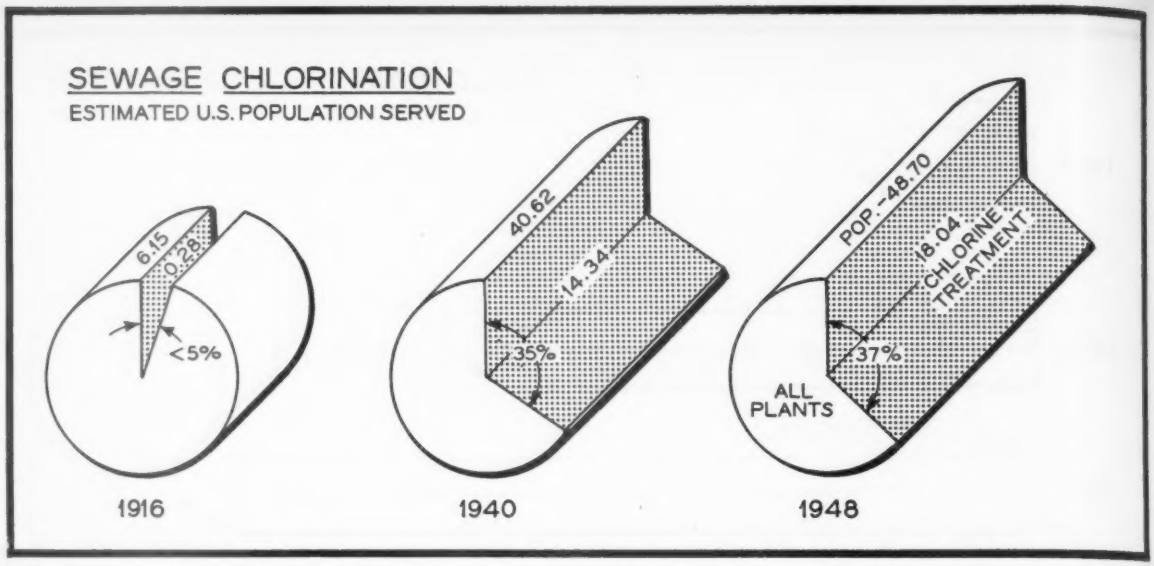

FIG. 11—2. U. S. POPULATION (in millions) served by sewage treatment facilities with (shaded) and without chlorine treatment: 1916-1948.[4,5]

including some finely divided inorganics) consume about 50 per cent of the chlorine added, and the settleable and soluble substances (unstable organics, stable inorganics) each consume about 25 per cent. Only a negligible amount is consumed by bacterial cells and higher biological forms.[1]

Bacteria and Other Organisms: The biological composition of sewage is extremely variable in both types and numbers. Moreover, some industrial wastes may be heavily contaminated with bacteria and other organisms, while others may be completely devoid of life. Every waste must be considered separately, therefore, in order to establish the chlorine requirements to effect complete or partial disinfection.

Chlorine Disinfection

The destruction of bacteria and other organisms is the principal use of chlorine in waste treatment. The extent to which biological destruction or attenuation occurs depends on such factors as the amount and form of available chlorine, contact time and temperature, and the composition of the waste being treated, all in terms of the various factors previously highlighted.

Chlorine Requirements: To effect bacteria kill it is not absolutely essential to apply a chlorine dose sufficient to produce a measurable residual. Reductions in bacterial concentration can be and are effected through marginal chlorination, the amount varying with the proportion of the chlorine demand satisfied. Obviously, this is subject to wide variations and depends largely on the character and strength of the waste being treated.

Estimated chlorine requirements for disinfecting normal sanitary sewage are listed in Table II.

Chemical reducing substances common to all wastes in varying amounts may react with chloride to form compounds having little or no bactericidal capacity. The formation of chloramines by the action of chlorine on nitrogenous constituents of wastes renders these constituents unsuitable as food sources; moreover, as already noted, they do possess definite disinfecting power. In sewage treatment, in fact, free residual chlorination is rarely practiced.

Irrespective of the kind or amount of available chlorine, that which does not penetrate dense suspended solids is ineffective in the destruction of bacteria and other organisms encased by these solids. Waste effluents containing substantial amounts of suspended solids that are discharged into water bodies may cause serious aftergrowths due to the release of imbedded bacteria by action of hydraulic turbulence that offtimes prevails. Furthermore, some biological species that are relatively unaffected by chlorine dosages typically encountered in waste treatment practices may reproduce prolifically in the absence of large numbers of metabolically-competitive, chlorine-susceptible forms.

The effect of temperature on the bactericidal action of chlorine is considered negligible within normal temperature limits. A major increase usually will increase the bactericidal effect proportionately. Where pH levels in excess of 8.5 are encountered, the bactericidal efficiency of chlorine is markedly impaired.

In employing chlorine in waste

Table II

Estimated Chlorine Required for Disinfecting Normal Sanitary Sewage

Treatment	Ten-State Standards[2] mg/L Chlorine	FSIWA[1] mg/L Chlorine
Pre-chlorination (mechanically cleaned tanks)	20—25	—
Raw Sewage	—	6—12 (fresh) 12—25 (septic)
Primary Effluent	20	—
Trickling Filter Effluent	15	3—10
Activated Sludge Effluent	8	2—8
Sand Filter Effluent	6	1—5

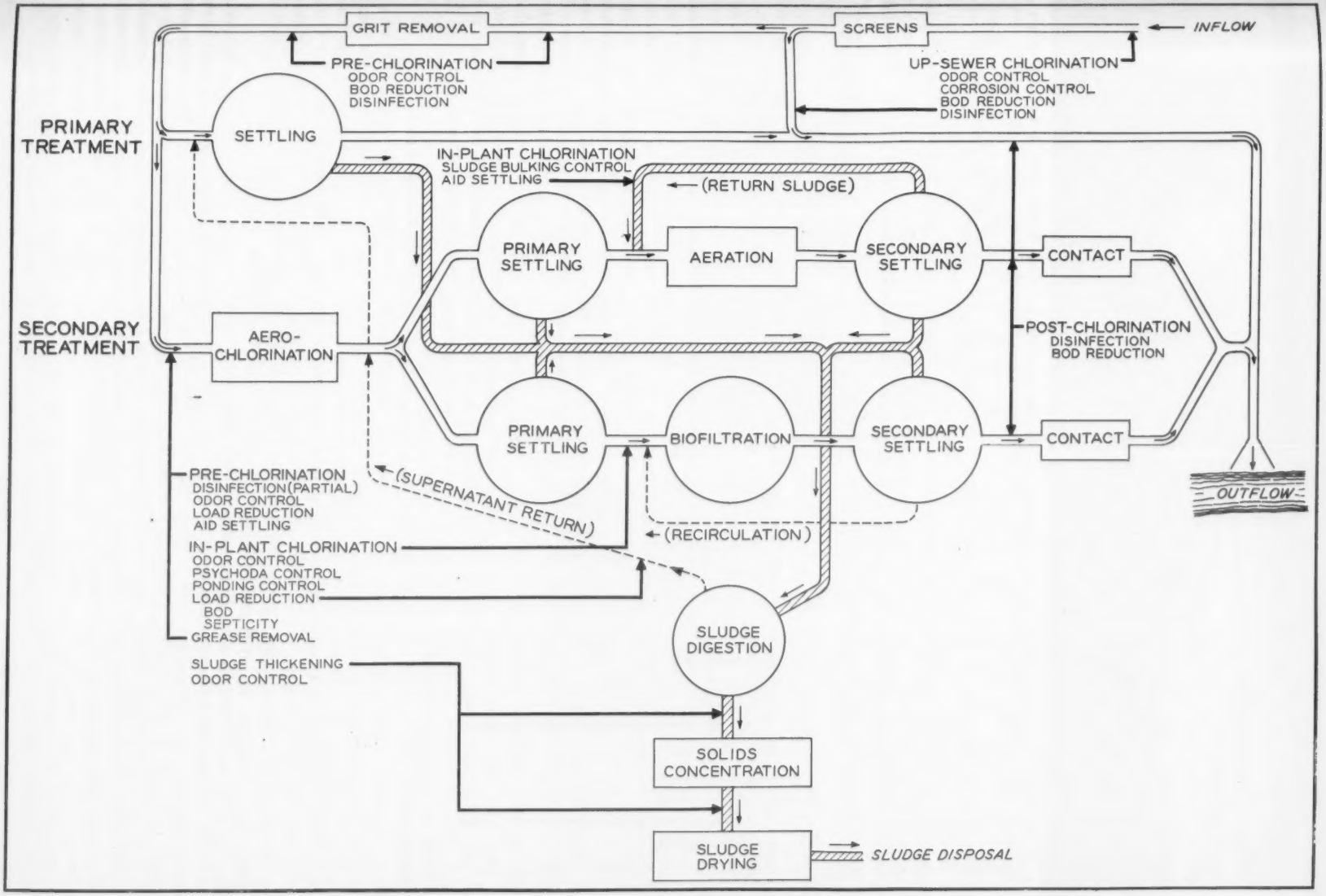

FIG. 11—3. APPLICATIONS of chlorine in sewage treatment processes.

FIG. 11—4. PONDING of trickling filters can be alleviated by chlorine treatment. These before and after photographs at Elgin, Ill. shows effect of 3000 lb of chlorine per acre applied over a 25 day period.

treatment processes, care must be exercised to select the point(s) of application and dosages in such a manner as to accomplish the objective as efficiently as possible without interference to the action of saprophytic organisms essential to aerobic or anaerobic purification processes.

Point(s) of Application: Flexibility in operation should be provided so that chlorine can be applied wherever it can best accomplish the desired objective. When that objective is disinfection primarily, *pre-* and/or *post-chlorination* usually is employed. *Up-sewer* chlorination (i.e., ahead of the treatment plant) should be employed for disinfection only in those instances where subsequent treatment is limited to screening. It is inefficient because the chlorine demand is great and the chlorine available can not fully penetrate the bacteria-laden solids. (As will be noted later, however, up-sewer chlorination frequently is applicable for many purposes other than disinfection.)

When secondary waste treatment is provided, *post-chlorination* is practiced where disinfection is indicated. Chlorine is applied at a contact tank, preceding the effluent discharge, or at the influent of the final clarifier. The latter is increasingly employed except where contra-indicated by activated sludge and biological filter recirculation practices. *Pre-chlorination* in dosages necessary to effect disinfection also is contra-indicated where subsequent biological processes are involved. Lesser amounts of chlorine for other purposes, however, can be applied throughout the treatment plant as later discussed.

When only primary treatment is provided, limited reductions in bacterial density are accomplished and disinfection often is required by local authorities. Either or both pre- and post-chlorination may be employed; split chlorination practices are becoming increasingly popular. Applied at one or more points in the interceptor, or to raw or screened sewage ahead of the settling units, maximum contact is provided. Moreover, though disinfection is the primary objective, other benefits may accrue such as odor control, septicity control and improved settling.

Terminal application alone is satisfactory but usually is less desirable since a special tank or other means of adequate contact with chlorine usually must be provided; also, the chlorine demand actually may be greater than that of the raw sewage if the waste is stale or putrescing.

Continuity of Disinfection: The basic criterion used by most authorities in establishing the need for disinfection is the effect of the discharged wastes on the receiving water body and its subsequent uses. Instances where it is required might include those numerous facilities in close proximity to public water supply intakes, bathing, other recreational and shellfish propogation areas, or where crop irrigation or dairy cattle herd pastures are involved. Obviously, then, requirements will vary from place to place as well as at any time for a given facility. Disinfection is practiced continuously, intermittently, or not at all, depending on local considerations and subject to the requirements[3] of the appropriate regulatory authority involved.

Residual Requirements: From the foregoing discussion it is apparent that the considerable variations in the chemical and bacteriological character of wastes, and in disinfection objectives, preclude the establishment of rigid, uniform chlorine residual requirements. The value of maintaining a fixed chlorine residual is based principally on local demonstration of the effect of such practices on desired bacterial kills, and conformance to requirements relative to the quality of the plant effluent or of the receiving water at any downstream point. More than 30 states have no official position relative to the maintenance of a fixed chlorine residual of waste effluents although an equal number have adopted the "Ten-State Standards"[2] recommendation that chlorination equipment should have sufficient capacity to be capable of producing a residual of 2.0 mg/L in the final effluent. As in water works practice, the only positive means of establishing the effectiveness of sewage disinfection is by measuring the bacterial population after treatment and at the point of water re-use.

Other Chlorine Uses

While the use of chlorine as a disinfectant in waste treatment constitutes its most important application, for odor control and as an adjunct to primary and secondary treatment processes the benefits are manifold (see Fig. II-3).

Odor Control: Most sanitary wastes are potential sources of odors because they present an ideal environment for prolific bacterial metabolism and subsequent putrefaction (anaerobic) of organic waste solids. The composition of sewage and industrial wastes often is such that chemical treatment is indicated to supplement other conventional treatment practices. Chlorine, being easy to apply and quick-acting, is one of the more important chemicals used for control of odors,

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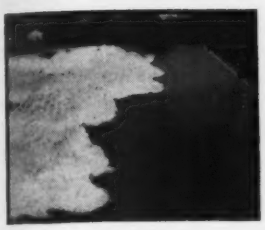

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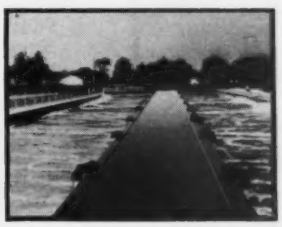

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FIG. 11—5. APPLICATIONS of chlorine in sewage and industrial wastes treatment for resources conservation and pollution abatement.

particularly that esthetically objectionable and economically important product of anaerobic decomposition, hydrogen sulfide.

In theory, about 2 parts by weight of chlorine are required to precipitate sulfur for each part by weight of sulfide as H_2S; and, about 8 parts by weight are required to oxidize it to sulfate. These reactions take place at pH 5 to 9, but the first occurs optimally at the lower pH level and the second, at the higher level. Because of the effect of other chlorine-demanding substances, considerably more chlorine actually may be needed to effect these reactions.

Corrosion Control: Concrete and metal sewage systems conveying wastes having in excess of about 1 mg/L hydrogen sulfide deteriorate, especially where the temperature is high and sluggish flows at low pH prevail. These conditions also enhance accelerated growth of slime-ensheathed, sulfate-reducing organisms that produce additional sulfide, a portion of which is absorbed by moisture and grease above the liquid surface and is subsequently oxidized into sulfuric acid.

Sub-residual, up-sewer chlorination (usually at somewhat greater dosages than that required for odor control only) reduces H_2S concentration to an amount which will not be vaporized. Higher concentrations of chlorine are indicated for the destruction of slimes.

BOD Reduction: It has been amply demonstrated that chlorine will reduce the biological oxygen demand of a waste within certain reasonably well defined limits — by 15 to 30 per cent. The practice is not advocated as a substitute for properly designed and operated treatment processes. It is recommended, however, for reducing the BOD load on various unit processes, for minimizing the effect of such overloading caused by unusual flows, the presence of industrial wastes, digester supernatant or activated sludge return to inflow, and for other purposes.

BOD reduction usually is effected where up-sewer chlorination is practiced for odor control, pre-chlorination for disinfection or odor control, or wherever else chlorine is applied for any purpose ahead of or within the treatment plant. While free residual chlorination will effect as much as an 80 per cent BOD reduction in activated sludge effluents, these and other secondary treatment effluents seldom are chlorinated for the specific purpose of BOD reduction, except possibly where the units are grossly overloaded. Similarly, while free residual chlorination of raw sewage might effect as much as a 50 per cent BOD reduction, this treatment is impractical under usual circumstances, patrially because of the high concentration of ammonium compounds and other nitrogenous materials.

In practice a reduction of 5-day BOD of 15 to 30 per cent can be anticipated in the presence of 10-min chlorine residuals of 0.2 to 0.5 mg/L. Furthermore, significant additional overall BOD reduction is effected under any condition for which chlorine is employed.[1]

Biological Filter Operation: The utility of chlorine as an adjunct to trickling filter operation has been demonstrated widely. The release of odors over trickling filters associated with the treatment of septic sewage usually can be controlled by pre-chlorinating at the dosage chamber. Frequently to preclude septicization of the waste during primary treatment, chlorine applied after screening is indicated. To avoid interfering with the biological nature of the process only a portion of the chlorine demand should be satisfied — usually about 50 to 75 per cent — and there should be no residual chlorine at the filter.

In addition to this and other benefits of up-sewer and pre-chlorination already outlined, the psychoda fly nuisance especially associated with filter operation during warm weather offtimes is amendable to chlorine treatment. Various successful treatment regimens have been reported, but optimum treatment should be based on local experiences.

Filter ponding, due to the accumulation of excess solids that clog the interstices of the filter, sometimes can be alleviated by chlorine (see Fig. II-4). Intermittent, shock treatment of 5 to 10 mg/L residual at the filter nozzles during periods of low chlorine demand, or continuous chlorine application to produce a residual of 1 to 2 mg/L usually will be effective in loosening excess zoogleal material that can then be flushed from the filter. Where clogging has penetrated the bed deeply or otherwise is due to

the accumulation of insoluble mineral particulates, chlorine treatment usually is of little lasting or no benefit.

Sludge Bulking Control: Sludge bulking, manifested by poor settling of activated sludge in secondary clarifiers, sometimes can be eliminated with chlorine. In instances involving excessive overloading of treatment facilities, prechlorination of the plant influent often is beneficial. Where bulking of activated sludge is attributable to an abnormal concentration of filamentous fungi, the application of chlorine to return activated sludge at a point which allows 2 to 3 min contact before mixing with the sewage also may be of benefit.

The proper chlorine dosage is dependent on the sludge index and the amount of dry solids in, and the rate of, the return sludge. It appears that continuous chlorination yields results superior to those obtained by intermittent practice.

Miscellaneous: Among those other applications in which the utility of chlorine has been demonstrated are:

Grease Control—aero-chlorination preliminary to primary settling.

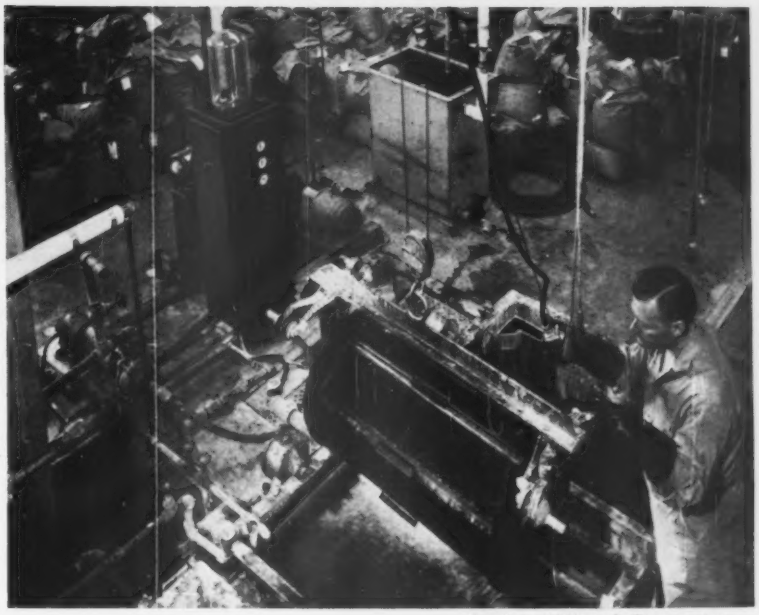
Sludge thickening—chlorine applied to waste activated sludge in thickening units.

Digester supernatant—chlorination preceding discharge to primary settling units, to reduce the load and minimize odors.

Digester sludge—chlorination prior to discharge to drying beds, for odor control.

Coagulation Aid—to improve the settleability of wastes, in conjunction with various chemical or biochemical processes.

Foam Control and Miscellaneous Plant Improvements—chlorine applied to accomplish a specific objective, or achieved incident to chlorine treatment for some other purpose.



Courtesy Wallace & Tiernan, Inc.

FIG. 11—6. ALKALINE chlorine oxidation of cyanide waste from cadmium electro-plating operation. Foreground: Work being prepared for plating in cleaning tanks. Background (l. to r.): Collecting sumps (under grating), chlorinator, booster pumps, and plant water suction chambers. The reaction tank is not shown.

Industrial Wastes Chlorination

Biological and chemical wastes of increasing complexity are products of modern technology. Over the past quarter century, the utility of chlorine as a waste treatment chemical and disinfectant has been established (see Fig. II-5). Some wastes have such a high chlorine demand that other treatment methods are dictated for practical reasons. Similarly, certain other industrial wastes are unaffected by chlorine.

Of the chemical wastes for which chlorine treatment is commonly employed, cyanide-containing, metal-cleaning and electroplating wastes, and phenol-containing gas, coke or other petrochemical wastes, are the most outstanding. The presence of cyanides and phenols in untreated wastes discharged to surface waters imposes a potential public health hazard and often creates economic and esthetic problems of great magnitude. These chemicals can be readily oxidized by chlorine under certain, well-established conditions (see Fig. II-6). In the latter case, if the concentration is very high, phenol recovery preliminary to chlorine treatment may be indicated.

In the treatment or pretreatment of textile wastes there are many applications of chlorine. It is used as a coagulant aid, for bleaching, BOD reduction, septicity control, grease recovery and other incidental purposes. Each waste constitutes a special problem that requires thorough study on the suitability and means of chlorine application.

As an adjunct to conventional and modified biological treatment processes adaptable to food processing wastes, chlorine frequently is employed for BOD, odor and septicity control and for disinfection, where indicated.

The reuse of treated sewage and some industrial waste effluents and process waters is made possible by chlorine treatment. Chlorine serves as a disinfectant to prevent disease transmission, to control slimes, marine and other biological nuisance organisms, in addition to oxidizing objectionable waste products. Resources conservation and water pollution abatement are thereby enhanced—a factor of growing importance and necessity in this increasingly-competitive, technological era of modern times.

Acknowledgment

Figures illustrating typical biological and chemical effects of chlorine in the treatment of water and wastes were developed from a concept suggested by Harry A. Faber, formerly research chemist of The Chlorine Institute.

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Sludge Disposal

by DON E. BLOODGOOD

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IN THE TREATMENT of sewage the main objective is the removal of the solids from the liquid portion. The removed solids—primary sludge, septic tank cleanings, activated sludge, chemically precipitated solids, humus from trickling filters, Imhoff sludge, solids from separate sludge digestion —all require further attention before the sewage can be said to be purified. In many instances the remaining solids are as much of a problem as the purification of the sewage.

The sludge that must be processed has been handled by any of the following methods, or by combinations of them:

1. Vacuum filtration.
2. Incineration.
3. Dumping at sea.
4. Drying on sand beds.
5. Lagooning.
6. Kiln drying.
7. Fertilizer production.
8. Vitamin B_{12} production.
9. Freezing.
10. Centrifuging.
11. Flotation.
12. Composting.

Vacuum Filtration

Practically all of the sludges that have been produced have been dewatered on vacuum filters. Activated sludge is being filtered at large plants such as those in Milwaukee, Wis., and Chicago, Ill. Primary sludge is filtered at Minneapolis-St. Paul, as well as in many other places. Sludges containing precipitated chemicals are filtered at East Chicago, Ind. It is safe to say that attempts have been made to filter any and all sludges.

In vacuum filtration of sludges it is necessary to add chemicals that "condition" the sludge (coagulate the solids) so that the water is more easily separated from the solid particles. The chemicals that are commonly used include ferric chloride, ferric sulphate, chlorinated copperas, alum, aluminum chloride, lime, and sulphuric acid.

Ferric chloride has been said to have two effects on the solids. It is believed that the charges on the particles are neutralized by the ferric chloride, thus making it easy for them to clump together. It also has been said that the ferric chloride has a tanning or shrinking effect on the sludge particles.

The quantity of ferric chloride used is often stated as a percentage of the dry weight of the sludge solids. It is interesting to note that it has been found that the most rapid filtration occurs at a certain pH, depending on the kind of sludge and the chemical being used. The same pH is desired even when there is a different concentration of solids in the sludge.

Center [1] has written quite extensively about the coagulant requirements of sludges being dewatered by vacuum filtration and has given some methods for calculating the quantity of chemical or chemicals required for filtering the different sludges. He says that in considering the problems encountered in filtration of sludges it is necessary to realize that water makes up a large percentage of any sludge, and that in the decomposition of sludges the organic solids are destroyed, thereby increasing the concentration of minerals in the water fraction of sludges of similar concentration that then remain. He goes on to say that there are instances where bicarbonates are known to increase being digested. Some bicarbonates are probably also trapped in the sludge almost 100-fold while the sludge is particles and as a consequence, add to the chemical requirement for satisfactory filtration of the sludge.

The reactions that take place between the chemicals and the bicarbonates in the liquids of the sludges are probably similar to the following:

$$FeCl_3 + 3\ NH_4HCO_3 \rightleftarrows Fe(OH)_3 + 3\ NH_4Cl + 3\ CO_2 \quad (1)$$

and

$$2\ FeCl_3 + Ca(HCO_3)_2 \rightleftarrows 2\ Fe(OH)_3 + 3\ CaCl_2 + 6\ CO_2 \quad (2)$$

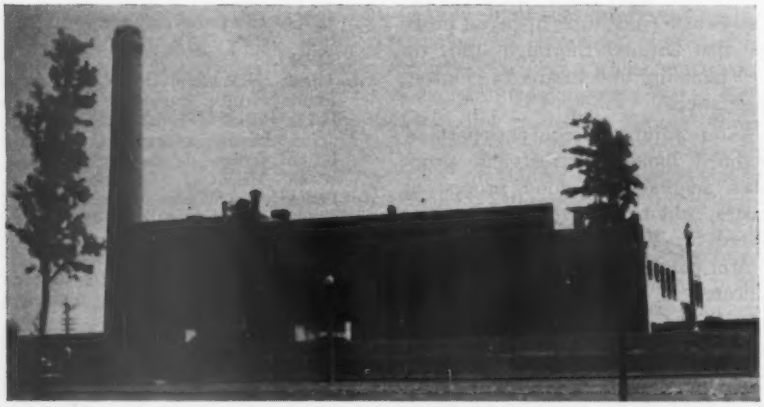
It can be shown from Eqs. 1 and 2 that it requires 1.08 parts of ferric chloride for every equivalent part of calcium carbonate present as alkalinity in the liquids of the sludge. Some digested sludges have been found to contain as much as 3,500 ppm of alkalinity.

Genter believes that the solids demand for coagulant depends on the percentage of solids present in the sludge and the percentage of volatile solids. He has developed formula:

$$X = 1.08\ Y_1 + 1.6\ Y_2 \quad (3)$$

in which X = the total ferric chloride dose as a percentage of the solids, Y_1 = the percentage of sludge water × ppm. alkalinity × 0.0001 divided by percentage of sludge solids, and Y_2 = the ratio of volatile to ash in a sludge.

In an example where the alkalinity is 260 ppm, solids 9.35 percent, water 90.65 percent, volatile 62.1 percent,



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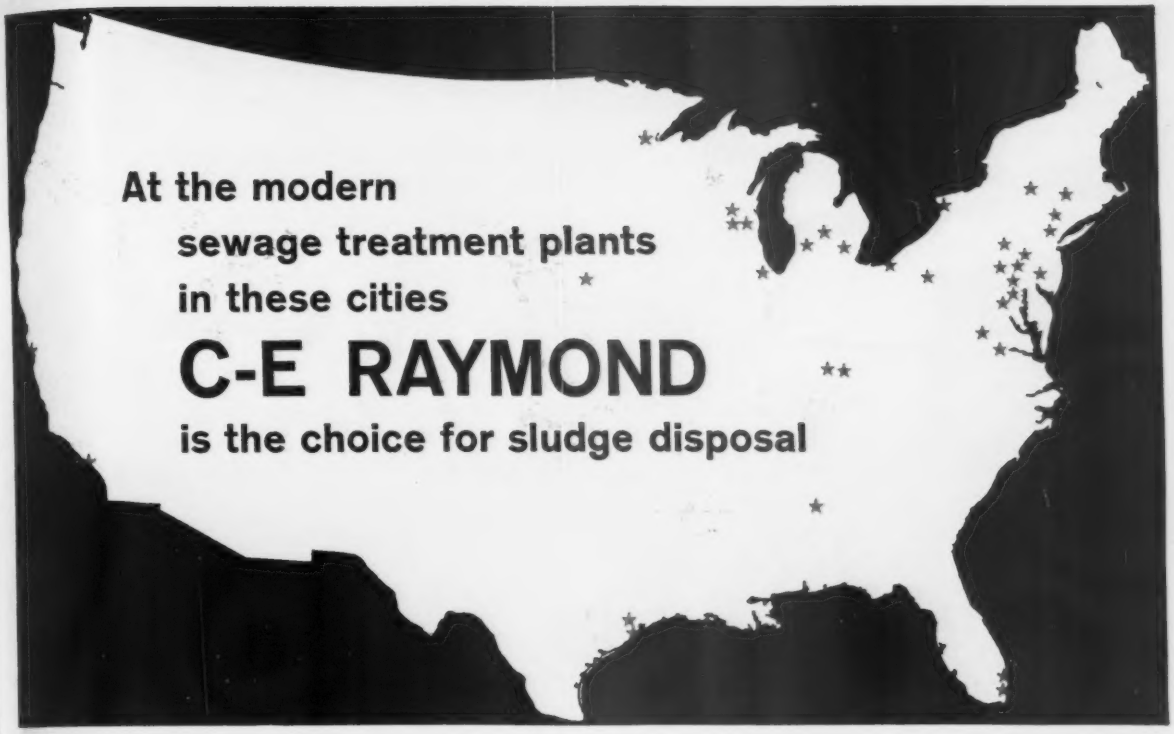

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ALSO FLASH DRYING AND INCINERATION FOR INDUSTRIAL WASTE DISPOSAL

FIRST SUCCESSFUL full-scale sludge furnace was this installation at Dearborn, Mich.

and the ash 37.9 percent, the calculated requirement would be 2.89 percent. From this example it can be seen that about 10 percent of the coagulant is required for the reaction with the alkalinity. Genter and others have shown that by removing the alkalinity with a process of washing called "elutriation" it is possible to reduce materially the chemical requirement in filtering sewage sludges.

The filtering medium on vacuum filters has been one of the problems that has perplexed operators in the past and efforts are still being made to find filtering media having long life and capable of being operated for long periods without washing. Cottons, wools, and the new synthetic fibers have all been used. Each filter operator has his own opinion as to which material gives the most economical operation in his plant.

The coil spring filter uses no cloth and there is no danger of the filter medium rotting during shutdown periods.

Kirkland, Wash., filters digested sludge at a cost of $6.25 per cubic yard of filter cake for chemicals, labor, and maintenance. The sludge sells for $3 to $5 per cubic yard.

The sludge from vacuum filtration may be placed as fill, or dried and used as fertilizer, or incinerated and the ash discharged as fill.

Incineration

Sludges from all processes have been incinerated. For successful operation it is necessary to dewater the sludges to some extent before burning is attempted. The more common practice is to vacuum filter sludge before incineration, but there is no reason why sludges dried on sand beds or in lagoons cannot be incinerated.

Owen [2] has said that the best way to determine the quality of the sludge for incineration is to know the ultimate analysis, but even this is not exact information. Average data on the ultimate analysis of various waste materials are given in Table 1, taken from Owen's paper. He points out that the sludge analysis will vary because of the different concentrations of grease that may be found in sewage sludges; some have shown as high as 13,900 Btu per pound, and some raw sludges have been found to contain 75 percent combustible matter, although digested sludges may contain only 50 percent combustible matter.

TABLE 1

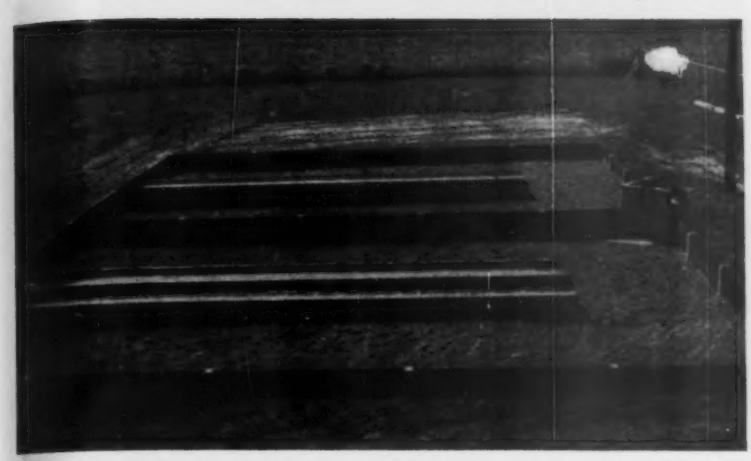
Ultimate Analysis of Waste Materials

Material	Carbon	Hydrogen	Oxygen	Nitrogen	Btu/lb
Wood	53.5	6.0	40.4	0.1	9,900
Garbage	54.5	7.5	35.0	1.0	10,000
Rubbish	53.0	6.0	37.5	3.5	9,000
Sludge	55.0	7.0	35.0	3.0	10,000

The vertical multiple-hearth furnace has been used extensively in the disposal of sewage sludges. In these furnaces the wet sludge cake is injected on the top hearth and dries as it passes from the top hearth down. On the lower hearth combustion takes place and the heat released dries incoming sludge. The ash is collected at the bottom and can be transported by air, water, or vehicle to the dumping ground.

In the incinerator the moisture admitted with the sludge must be raised to 212°F, changed into steam, then raised to the combustion temperature in the furnace or to the final gas outlet temperature. The ash must be raised to the final exit temperature. A sufficient amount of air must be admitted to oxidize all of the combustible matter present. The combustible matter must be raised to the ignition point and all of the products of combustion must be raised to the gas outlet temperature.

The heat losses in an incinerator must be made up by energy from some source. The heat losses commonly considered include heat radiated through the furnace walls, heat



NEW OPEN, DRYING BEDS at Whiteland, Ind., use plank stop-log sides and provide easy loading by elevated concrete truck runways.

used in raising the temperature of excess air, heat lost in ash discharge, and heat lost in air or water used in cooling certain parts of the furnace.

The heat available from a particular sludge can be estimated if analysis of the material to be burned is available; however, it can be noted from Table 2 [3] that there is considerable variation in the calorific values of sludges, so the calculated heat value may be considerably in error.

In some places the sludge is only dried and the solids are then removed and sold as fertilizer. In such instances all of the heat required for the drying must come from coal, oil or gas supplied from outside sources.

Freezing

Freezing of sludge to facilitate dewatering has not been practiced in the United States. Many a sewage plant operator has observed that frozen sludge dewaters very quickly and the solids after thawing make excellent humus, having lost the sticky characteristic of partially dried sludge.

It has been speculated that the freezing action breaks the cell walls that retain the internal moisture in sludge. It is believed that if sludge could be frozen and thawed without the loss of any great amount of energy the process would be used extensively for preparing sludge for disposal. Clements *et al.* [4] have experimented with freezing and they believe that complete freezing with chemicals can be used successfully if power costs can be kept very low. At the present time freezing can be taken advantage of only as it can be utilized in nature. Sludge that has been frozen on a drying bed will be a better material for use as a fertilizer when it thaws. Sludge that freezes in a shallow lagoon will dewater readily when thawed, providing it is possible for the water to drain away from the solids.

TABLE 2

Calorific Value of Sludges

	Type of Sludge	Btu/lb. Dry Solids	Btu/lb. Combustible Solids
A	Digested	5,975	12,480
B	Digested	5,830	10,750
C	Digested	5,290	8,980
D	Digested	4,980	9,500
E	Fresh	9,485	13,855
F	Fresh	10,285	13,905
G	Fresh	9,125	11,415
H	Fresh	7,010	10,155

Liquid Sludge Disposal

One of the most troublesome problems in the disposal of sludges has been the separation of the liquid and the solids. Some of the complaints about processes used for separating the water and solids have been that filtration is expensive and that drying beds are unpredictable because of weather conditions. Whether these complaints are just, one cannot positively conclude because of many variables. It can be said with safety, however, that if sludge could be disposed of without separating the solids from the liquid and without any effort or expense there would be great rejoicing.

Sludges contain so much water that liquid sludge disposal requires the handling of excessive quantities of water.

The quantity of solids that can be removed in a 1,000-gallon tank truck amounts to only about 800 pounds, while the 1,000 gallons weighs about 4 tons. The manpower required in handling the liquid is, of course, very much less than that required in the handling of 800 pounds of solids. Ross [5] has reported that it takes about one-twelfth the time to load liquid sludge that it does to load drying bed sludge. If the 800 pounds of solids are in sludge from a drying bed they would weigh about 1 ton and would occupy a volume of about 1 cubic yard.

Liquid sludge is hauled to sea for dumping in some instances. This makes a satisfactory way of disposal in those places where it is possible to have water shipping facilities. The cost of disposal is not reported as being unusually low. New York City has practiced this method of disposal for many years.

When liquid sludge disposal by truck is practiced it is not possible to operate the facility during all seasons because it is not possible to haul onto farm land during wet weather. In those cases where ample storage space is provided in digestion tanks this is not a serious problem. In some instances lagoons are provided and sludge is discharged to them during the time that trucking cannot be done.

Liquid sludge must be digested because of the possible nuisances that would arise if primary or activated sludges were to be discharged on the land.

Backmeyer [6] discontinued the use of vacuum filtration at Marion, Ind., and this city has practiced liquid sludge disposal since 1943 with apparent success. The cost of liquid sludge disposal was reported to be 77 percent of the cost of vacuum filtration with no accounting for the costs for equipment being used.

Drying Beds

Drying beds are a very common method for the disposal of digested sewage sludge. A few attempts have been made to add other sludges to drying beds, but they have not been successful.

At Fort Wayne, Ind. [7], it has been the practice to make more than one application to a bed before the sludge cake is removed. This is not a conventional procedure and it is surprising that it is reported to give greater bed utilization.

The Fort Wayne open drying beds are not cleaned between the first of December and the middle of March. This necessitates a sludge digestion tank storage capacity large enough to hold a 3½-month accumulation unless sludge lagoons are utilized during the winter period.

During the months when the beds are being cleaned it takes two to five days to remove the sludge from one bed that contains 19,555 square feet.

Covered drying beds are advantageous where rain interferes with the drying or cleaning. The effect of rain has not been definitely determined because it seems to depend on the state of dryness of the sludge at the time of the precipitation. If the sludge has dried to the point of cracking, the rain does not seem to delay materially the removal of the sludge.

Sludge that does not crack shows evidence of incomplete digestion and such sludge will not dry in any reasonable time.

Richmond, Ind., reports that the shortest time between loading and removing the sludge from a drying bed has been ten days.

At Dayton, Ohio [8], the drying rate for glass covered beds is 17 pounds of dry solids per square foot per year, whereas on open beds the loading was 16 pounds.

Sludge when removed from drying beds should contain about 70 percent moisture if it is to be used for fill or fertilizer.

COVERED DRYING BEDS, such as these at Franklin, Ind., reduce weather problem in sludge drying.

Fertilizer Production

Activated sludge and digested sludges of all kinds have been dried and sold as fertilizer. The organic material, plus the nitrogen, phosphoric acid, and potash, in the sewage sludge make it a desirable soil builder. The plant food materials present are not in sufficient quantity to make the dried sludge valuable from that standpoint. It is believed that digested sludge is somewhat comparable to farm manure in its content of fertilizer materials. Milorganite, the product made in Milwaukee from activated sludge, contains about 6.0 percent of nitrogen, 3.4 percent phosphoric acid, and 0.65 percent potash.

To produce fertilizer the cake from vacuum filtration is dried in either rotary or flash drying equipment. The filter cake may contain 75 to 85 percent moisture and sludge cake containing more than 50 percent moisture has a tendency to form in balls in a drier. Therefore, it is necessary to mix previously dried solids with the filter cake to bring the moisture content of the material to be dried below the 50 percent figure previously mentioned.

Kiln dried sludges are heated to temperatures that preclude possibilities of pathogenic bacteria or intestinal parasites being carried by the sludge [9].

At Milwaukee the dried sludge is being processed to recover vitamin B_{12}. Extraction of the vitamin does not adversely affect the value of the sludge as a fertilizer and soil builder.

Composting

Many attempts have been made to compost sewage sludge with other organic materials. It cannot be said that composting cannot be accomplished, even though it is not done extensively. The composting or decomposition takes place in a satisfactory manner when the right conditions are maintained. To date, the speed with which the composting takes place is slow, requiring retention of the materials for longer than seems feasible. There is considerable labor involved in the operation of the process because it has been necessary to turn or mix the materials periodically as the decomposition progresses.

The material remaining after composting is much like the leaf mold found in the woods. It is quite satisfactory for mulching trees and shrubs, but it is not necessarily free of pathogenic organisms unless it is heat dried prior to marketing.

Pumping to Sea

Pumping of waste sludge to sea perhaps should be considered as a method of liquid sludge disposal, except that the sludge is not hauled. The pumping of sludge to sea can be practiced only on the seacoast and then only where the conditions are such that there is no danger of contaminating the beaches in the vicinity of the discharge. It is the usual custom to digest the sewage sludge prior to discharge. The period of digestion accounts for a considerable decrease in the pathogenic bacteria found in the raw sludge. The digestion decreases the organics that will decompose at the point of discharge and, of course, in the decomposition prior to discharge considerable combustible gas is recovered.

The process of disposal at sea is not without potential dangers; therefore, it is necessary to make a very thorough study whenever it is considered as a method of disposal.

Summary

The problem of sludge disposal is as great or greater than that of purifying the sewage. There is no one way that seems better than all others for the disposal of sewage sludge.

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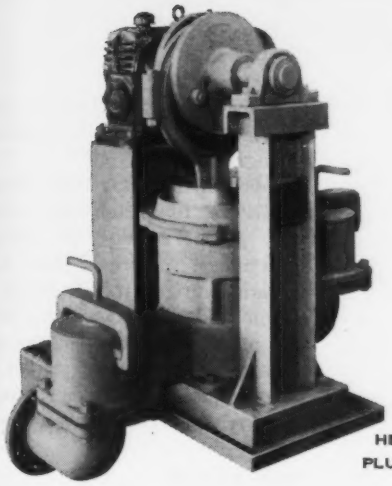

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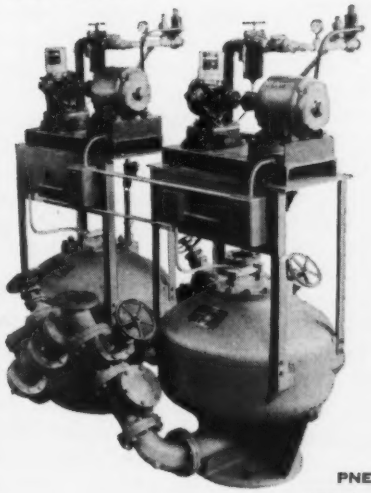

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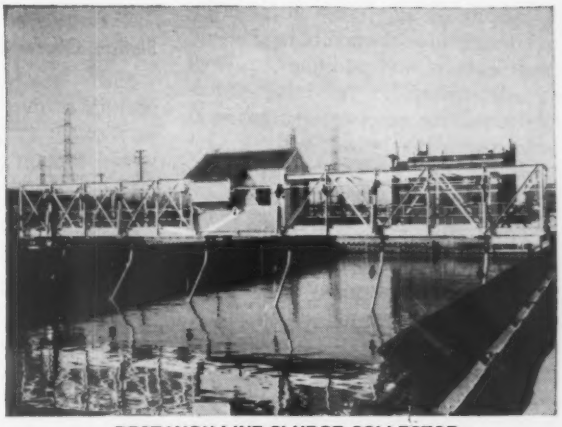

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RAW SLUDGE PUMPING SYSTEMS*

by ELMER E. ROSS

Superintendent, Sewage Treatment Plant, East Bay Municipal Utility District, Oakland, Calif.

A large part of the total operating and maintenance effort at the larger sewage treatment plants is devoted to the removal, processing, and disposal of the solids removed as sludge. Consequently, the sludge-handling system should receive careful consideration during the design stage if efficient and economical operation is to be achieved. As much flexibility as possible should be built into the pumping system because of the variable characteristics of sewage sludges. Proper consideration must also be given to the severity of service.

Despite the care taken in the original design and selection of equipment, modifications and additions, as well as adjustments in operating procedures, may be necessary if maximum economy is to be realized.

System Design

At the time the East Bay plant was designed, it was the practice at most small plants and at many of the larger plants to remove the settled sludge from the individual sedimentation tanks by means of air lifts or telescopic valves and pump it to one or more large storage tanks or vaults, whence it was repumped to the digesters, after being allowed to concentrate. Skimmings and floating sludge were also generally discharged to these tanks. Disadvantages of this general method include the release of odors and a large labor demand. However, advocates claimed that the solids content of the sludge fed to the digester could be kept uniformly high.

After considerable study it was concluded that equally good results could be achieved with a smaller capital investment and less operating labor by pumping the settled solids directly from the sumps in the sedimentation tanks to the digesters. The storage and concentration tanks were omitted and each of the ten sedimentation tanks was provided with a sludge pump arranged to discharge directly to the digesters through a single force main. Each pump was equipped with a variable-speed drive; a program timer was installed to permit automatic operation; and sample piping was provided to allow visual observation of the flow.

Small scum wells were provided in the common wall between every second tank and skimmings were to be pumped directly to the digesters by the sludge pumps. The piping system was arranged so that sludge could be drawn into the scum wells for observation from either the force main or the sludge sumps.

Sludge Characteristics

Little was known about the composition of the sludge other than that, in addition to the domestic solids, it would contain a variety of industrial wastes and would contain, seasonally, large quantities of fruit and vegetable canning wastes.

Force Main Design

Data on the flow of raw primary sludge in pipelines was found to be both meager and inconclusive. Published results of the best experimental work indicated the frictional resistance to the flow, for sludges containing six per cent solids, was approximately 1.5 times the value computed for water using a coefficient of 100 in the Hazen-Williams formula when the sludge velocity is 3 fps; and approximately equal to that for water when the velocity is 6 fps (1). For want of better information, the force main was sized to operate at velocities between 3 and 6 fps. To allow for the fact that the sludge was undigested and would at times be more concentrated, the pumping units were sized on the assumption that the frictional resistance would be four times that for water.

Raw Sludge Pump Selection

Two distinct classes of pumps were, and still are, commonly used for moving sewage sludge: the centrifugal pump and the reciprocating piston-type displacement pump. The relative merits of each class are matters on which designers and operators do not agree.

Centrifugal pumps were chosen in preference to piston-type displacement pumps because the latter are often noisy, require a great deal of operating for repairs because of their weight and size. Operating reports also indicated that when the sludge contained quantities of grit or other abrasive material frequent repacking and overhaul of pistons were required.

Visual Samplers

Soon after the plant was placed in operation, sampling devices consisting of lengths of 4-in. diameter pyrex pipe were installed on each of the raw sludge pumps and at other points where sludge samples are required. One end of the glass pipe is connected to the sludge piping by means of a quick-opening valve. Water for flushing and compressed air at a pressure slightly greater than the pipeline pressure are piped to the other end. A sample is obtained from the flow by opening the quick-opening valve and slowly exhausting the compressed air from the sampler. The collected sample can either be drained for analysis or returned to the flow without exposing the sludge to the atmosphere by repressuring the sampler with air. Operators can, with experience, very accurately estimate the concentration of the sludge by watching it flow into the sampler. Samplers of this type should be designed as pressure vessels, and should be properly guarded for the safety of operating personnel.

Operating Experience

During the six years the plant has been in operation it has been possible to achieve the intended results with the original facilities. As shown in Table I, the sludge fed to the digesters has each year averaged better than six per cent total solids; the amount of operating labor required has not been excessive; and there have been no odor problems in connection with this phase of operations.

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TABLE I
Raw Sludge Solids Concentration

Fiscal Year	Total Solids % Yearly Avg	Max Mo.	Min Mo.
1953	7.6	9.3	6.4
1954	6.3	7.0	5.6
1955	6.3	7.1	5.9
1956	6.1	7.0	5.0
1957	6.3	6.6	5.8

However, it has been necessary to modify and augment the original installation because sludge quantities have been much greater than predicted and grease, sand, and fine silt in the sludge have created operation and maintenance problems.

Grease

Ether soluble oils and greases comprise, on the average, 25 per cent of the sludge solids. This is not excessively high as compared with other plants of similar size, however, because the force main is buried in the ground, these materials separate from the sludge flow and deposit on the walls of the pipe. During the first month of operation grease deposits reduced the effective diameter of the 6-in. force main to less than 2 in. Even after the grease deposit was removed with augers and knives attached to power-operated sewer rods, the friction loss when pumping sludge containing six per cent total solids was twice the design value, or eight to ten times that for water. Experimental work by Brisbin[2] and others has since confirmed that friction losses, when pumping concentrated raw sludges, are of this order of magnitude. Because of the increased friction losses, and because the sludge quantities were greater than anticipated, it was necessary immediately to increase the horsepower of the sludge-pump drives, and to add a booster pump a short time later. The resulting increase in flow rate did not prevent the deposition of grease in the force main, but did lengthen the time between cleanings. The build-up was very gradual during the late spring and summer when the ground and sludge temperatures average 63 and 75°F, respectively. During the winter, when these temperatures drop as low as 53 and 60°F, the build-up was very rapid. At times it was necessary to clean the force main as often as three times a week. Attempts to remove or prevent the grease coating from forming by back-flushing with supernatant liquor, heated in the digester heaters to 100°F, were not successful.

Steam Generator

A search of literature disclosed that a similar problem at the Buffalo, N. Y. works had been solved by heating the pipeline with steam. Experimental work with a small steam-cleaning machine indicated that the grease deposit could be removed in this manner if sufficient heat was added to raise the temperature above 130°F.

A sludge-gas fired, fully automatic, forced recirculation-type steam-generator was installed so that its output of 100 boiler hp could be injected directly into the sludge force main near each sludge pump discharge.

Since installing the steam-generator the force main has been maintained at or near rated capacity by heating and flushing at intervals, the lengths of which vary with the season of the year. Except for the infrequent removal of stoppages caused by rags and trash, cleaning of the pipeline with sewer rods has been eliminated. Noise and vibration initially accompanied the direct injection of the steam into the pipeline. This was subsequently eliminated by the installation of a Venturi type pipeline heater.

Sand and Silt

Material identifiable as sand and silt annually averages 17 per cent of the total, or 65 per cent of the fixed solids in the raw sludge, and during the winter season monthly averages have been as high as 40 per cent of the total, or 90 per cent of the fixed solids. Sieve analysis of samples of this material taken from the raw sludge and from deposits in the digesters disclosed that the average particle size is less than 0.20 mm, which is the smallest size particle that the grit chambers will normally intercept.

The sand and silt in the raw sludge have caused pump maintenance costs to be excessive. It wears the tips off of the impellers, quickly dulls cutting edges, and opens up the internal clearances of the pumps to the point where they frequently clog with rags. Tramp metal is occasionally carried into the pumps with the sludge, where it lodges and causes twisted shafts and other damage. The high rotative speeds of the centrifugal pumps accelerate normal wear and cause increased damage by tramp metal.

During summer months these conditions have made it necessary to replace sludge pumps after an average of 800 hr of operation, which is equivalent to two replacements per year per sedimentation tank; and during the winter months after only 200 hr of operation, which is equivalent to eight replacements per year per tank. The cost of completely overhauling a pump, including removal from service and reinstallation, has averaged $218.

Attempts to decrease the frequency of sludge pump replacement and reduce repair cost included: removal of some of the cutting edges; hard-facing and chrome-plating the areas where wear was severest; and changing the material of some of the parts. These measures were only partly successful, and led to the investigation of other types of equipment.

Progressing-Cavity Pump

One of several types of pumping equipment considered during the course of this investigation was the helical-rotor, progressing-cavity pump. This pump, a modified screw-type pump, is simple in design and construction and has only two parts subject to wear, both of which can be replaced quickly and easily—desirable features from a maintenance standpoint. The delivery is uniform and the head-capacity relationship, like that for a piston pump, is nearly independent of the discharge head.

Progressing-cavity pumps are used in the process industries to handle sludges containing solids in suspension as large as ⅞-in. diameter, and to pump abrasive slurries. They have also been used in England to pump digested sewage sludge to vacuum filters, but the pumping of raw primary sludge which contains rags and trash had not been attempted as far as could be determined except in connection with experimental work by the Allegheny County (Pa.) Sanitary Authority[3]. Some doubt existed that they would successfully handle raw primary sludges without excessive clogging caused by rags winding around the exposed rotating shaft in the suction cavity, and by sticks and trash accumulating in the bend at the pump inlet.

A progressing-cavity pump was borrowed from the manufacturer to

determine if clogging would prevent its use for raw sludge at the East Bay works, where screens with 1-in. clear openings between bars are used to remove trash. It was temporarily installed in place of the original pump at the sedimentation tank which, because of its location, always receives the most rags and trash (Figure 1).

The test pump had a 6-in. suction and a 5-in. discharge and was V-belt driven by a variable-speed drive. The delivery could be varied from 80 to 160 gpm against a total head of 150 ft of water. It was equipped with an oil-resistant, synthetic-rubber stator and a chrome-plated tool-steel rotor, a combination of materials known to give good service under abrasive conditions.

A water seal was not installed on the packing gland which would be subjected to only the suction pressure, in this case 15 ft of water. An estimated annual saving in water cost of approximately $150 per pump would be realized if the water seal could be omitted successfully.

The suction cavity was inspected for rags once a day after the pump was first installed. Some rags were always found wrapped around the connecting link, but they did not build up to the point where the pump's performance was adversely affected. The inspection frequency was therefore gradually lengthened, and finally eliminated after about two weeks of operation.

The test pump was disassembled for the first time after approximately 19 months' service to determine the cause of a sudden loss of capacity and accompanying vibration. It was found that a sharp object passing through the pump had gouged a piece from the rubber stator making replacement necessary. Although the rotor showed only nominal wear, it was thought advisable to strip and replate it. Total cost of the repairs was $140 and the down time to replace the stator and rotor was approximately two hours. This was substantially less than the cost of repairing one of the centrifugal-type pumps. Replacement of the stator, for the same reason, was again necessary after about six months' additional operation.

Operating experience with the progressing-cavity pump at the East Bay works may be summarized as follows: (a) Delivery is constant and nearly independent of the head or the concentration of the sludge, which is extremely heavy and laden with sand and silt during the winter, and cannery wastes during the fall. (b) Overhaul frequency, compared with the centrifugal units, has been reduced more than 50 per cent because of the low rotative speed and the combination of rubber and chrome-plated wearing parts. (c) There has been no evidence of scoring of the shaft in the packing gland that would indicate a water seal is necessary. (d) Rags accumulate on the exposed shaft in the suction cavity, but the pump does not require cleaning more often than the original pumps when in good condition. (e) The rubber stator is susceptible to damage from sharp metal objects; the use of a magnet and a metal trap ahead of the pump possibly would prevent this. (f) Clogging in the suction piping or loss of suction have not occurred because of the ability of the pump to prime itself and maintain its prime at suction lifts as high as 28 in. of vacuum.

Although the progressing-cavity pump has been used successfully as a raw sludge pump at the East Bay plant, it needs much additional testing before it can be considered entirely satisfactory for this service.

Operating Routine

The following routine, developed and modified during six years of operation, is followed in the operation of the raw sludge pumping system.

1. The sludge collectors are operated continuously and the collected sludge is withdrawn from each of the sedimentation tanks at least once during each of the operating shifts to prevent septicity. The length of the pumping period varies with the season of the year, but averages about 30 min.

2. The sludge pumps are normally operated in pairs and are controlled automatically by the program-timer during the day and evening shifts, and manually during the morning shift to ensure that all of the day's accumulation of sludge has been removed. The concentration of the sludge leaving each tank is checked by the operator by means of the visual samplers before the pump is stopped. Skimmings are removed and pumped at the end of each sludge-pumping cycle.

3. The booster pump is operated in conjunction with all pumps except the three progressing-cavity pumps.

4. When it becomes necessary to remove the grease coating from the force main, the flow rate is reduced to 80 gpm and the sludge heated with steam to approximately 150°F. Several hours of operation at this rate of flow and temperature melt the grease deposit and restore the capacity of the force main.

Conclusions

On the basis of the material presented herein the following general conclusions appear to be justified:

1. Pumping raw sludge from batteries of sedimentation tanks directly to digestion systems or other disposal facilities is an economical procedure at large sewage treatment plants from both the capital-investment and operating-cost standpoints.

2. The solids concentration of raw sludges can be effectively controlled through the use of variable-speed pumps, visual samplers, and program timers.

3. The friction head, when pumping raw primary sewage sludge averaging six per cent solids, is approximately eight to ten times that for water.

4. The grease coatings which tend to form in raw sludge force mains can be effectively removed by injecting steam directly into the flow.

5. Raw primary sewage sludges can be pumped successfully with the larger progressing-cavity pumps if the sewage flow is properly screened prior to sedimentation.

Acknowledgement

The assistance of Gerson Chanin, Chief Sanitary Chemist, and G. H. Davis, Jr., Sewage Works Supervisor, in the preparation of this paper is gratefully acknowledged. The author is especially indebted to plant personnel for many valuable ideas and suggestions as to improvements and modifications of equipment and operating techniques.

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Digestion Control with Gas Diffusion

by PHILIP F. MORGAN and PETER J. NEUSPIEL

respectively, Prof. of Sanitary Engineering, State University of Iowa, Iowa City, Iowa, and Engineer, Chicago Pump Co., Chicago, Ill.

High-rate digestion of sewage sludge has attracted the attention of sanitary engineers during the past several years because it offers an opportunity for savings in new construction and for increasing the capacity of existing overloaded units. The use of high-rate digestion has made clear the relative importance of the two basic phases of treatment involved in digestion; that is, the biological phase, during which biochemical changes occur and the sludge is stabilized, and the mechanical phase, during which the volume of the sludge is reduced by withdrawal of supernatant liquor either before or after digestion.

These two phases are distinctly separate in high-rate systems, so that an optimum environment for biological life can be maintained during the biological phase and quiescent conditions for most effective gravity separation can be provided for in the mechanical phase. Two high-rate systems have been proposed for digesting sewage sludge.[1] One is based on the work in Iowa City where optimum conditions are maintained in the biological phase by recirculation of digester gas through diffusers located at the bottom center of the tank so the entire tank contents are kept in circulation.

This provides for control of the interaction of the gas and digesting sludge with the raw sludge added, prevents the formation of surface scum, and provides a means for removal of deposited sand. Supernatant liquor can be separated either before or after digestion, or can be disposed of with the digested sludge without separate sedimentation units.

Ed. Note: At the time of this study, Mr. Neuspiel was a Research Associate at State University of Iowa. This paper was presented at the 2nd Waste Treatment Conference at Manhattan College and is published here by permission.

In the other system, based on the work of Torpey,[2] optimum conditions are maintained in the biological phase by providing mechanical mixing, and only pre-concentrated sludge is used to provide a relatively high concentration of sludge in the digester. Normal digestion temperatures of approximately 35°C are used in both systems.

The research studies carried on at Iowa City during the past several years have been largely concerned with determining the optimum conditions for the biological phase and in establishing a relationship between laboratory bottle studies and pilot plant operations which can be used to project from the pilot plant to full-scale installations.

In the original work[1] with a 1,130-gallon pilot plant with gas recirculation, successful operation was maintained over a 10-month study period with an average loading of 0.46 lb of total solids per cubic foot per day and 0.28 lb of volatile solids per cubic foot per day at an average displacement period of 8.7 days with a gas production rate of 8.85 cubic feet per pound of volatile solids added.

Laboratory studies carried on in 8-liter bottles in parallel with the pilot plant indicated that tanks with gas circulation were more effective than tanks without gas circulation even though the gas rates used for these early studies were considerably less than the relative rate in the pilot plant. These studies also demonstrated that the results from the bottle studies were comparable to those from the pilot plant. Further investigation could then be continued on the bottles, where environmental conditions could be more easily controlled.

Sawyer and Schmidt,[3] and later Sawyer and Roy,[4] completed a series of laboratory studies on high-rate digestion. They confirmed that digestion could be successfully carried on at loadings characteristic of the high-rate system. In their first studies they mixed the digesting solids at regular intervals by manual shaking, but in the later studies they adopted a small gas pump for continuously recirculating gas to each bottle digester. Their results indicate that with gas mixing the loadings were comparable to the Iowa City results where a combination of manual mixing and manual gas recirculation had been used. They concluded that digestion periods as short as 10 days were practical without significant sacrifice of gas production or degradation of sludge quality.

Operating results from full-scale installations such as those at Columbus, Ohio,[5] and Moorhead, Minn.,[6] as well as observed results from several other installations where gas recirculation has been utilized, have confirmed the results of the bottle and pilot plant studies and the effectiveness of the process for digesting sewage sludge.

Continued progress undoubtedly will result in improved control methods, which will make possible higher design loadings and consequent savings in construction costs. Further research is needed to determine the minimum digestion time for varying environmental conditions. To try to accomplish this, work has been continued to obtain further information on (a) gas production rates in relation to raw sludge additions, (b) the effect of environmental control on digestion rates, and (c) better measurement of the performance of the digestion phase.

Gas Production Rates

It has been shown[7] that after each feed addition gas production and vola-

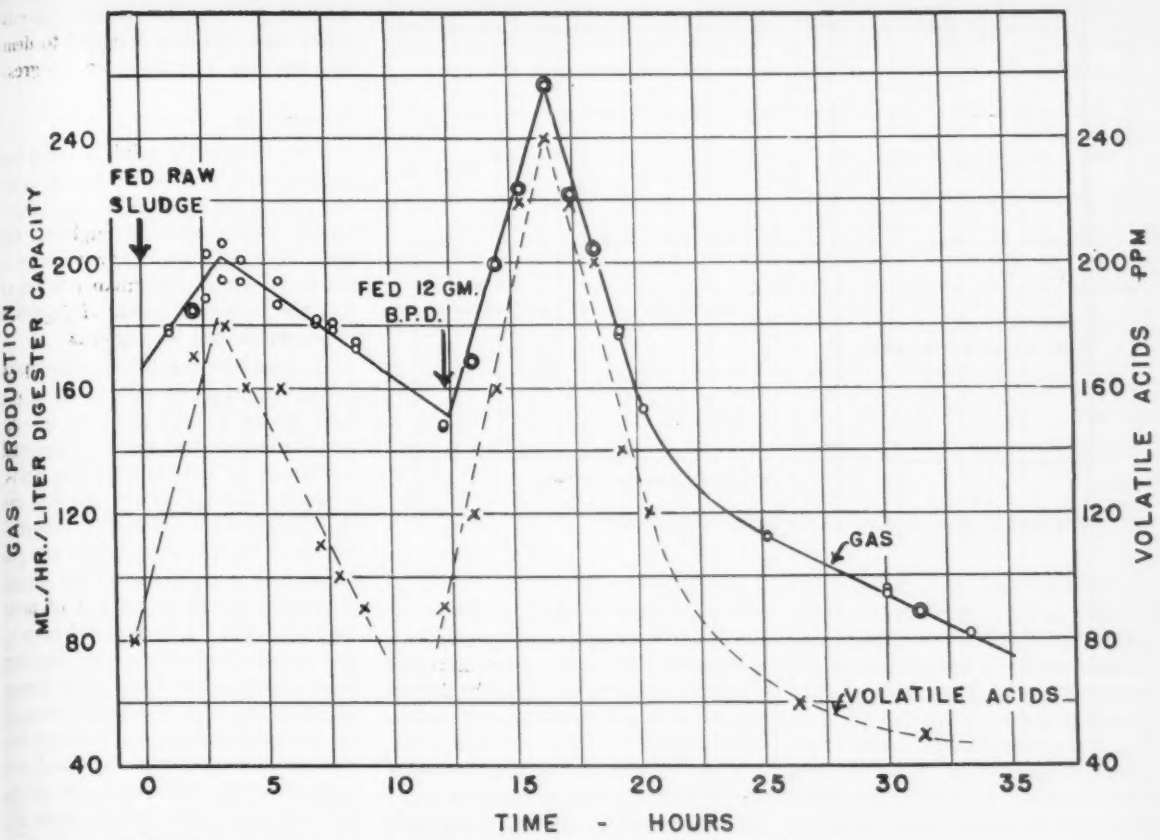

Fig. 1—GAS PRODUCTION rate and volatile acids concentration have definite relationship.

tile acid production follow a predictable pattern (Fig. 1). The digester under study had an operating volume of 7,500 ml; digested sludge was withdrawn once a day and raw sludge was fed twice a day at a rate which provided a 10-day displacement. On the day preceding that on which the data for Figure 1 were obtained, the digester loading was 0.34 lb of volatile solids per cubic foot per day. At zero time a half-day's feed was added, which provided 0.17 lb of volatile solids per cubic foot per half-day. Gas production rates and volatile acid concentration were determined at frequent intervals thereafter for 12 hr. At the end of this period a synthetic sludge composed of B.P.D. (bacto beef, bacto peptone and bacto dextrose 3:5:5 by weight) in a water solution was added at a loading rate of 0.10 lb per cubic foot per half-day and observations of gas production rates and volatile acid concentration were continued for 33 hours.

These results clearly demonstrate that gas is rapidly evolved after the addition of fresh sludge and that a characteristic peak production rate occurs 3 to 5 hr after sludge addition.

Following the peak production, the rate drops off on a straight line to one-half or three-quarters of the peak rate and then gradually further decreases to zero. Gas production from the synthetic sludge followed a similar pattern up to the peak rate and drop off, except that at the end of the 12 hr its rate was reduced to the base rate as if no synthetic sludge had been added, thus indicating that it was completely converted in 12 hr. It would appear from these results that when the environment can be controlled, anaerobic digestion is an exceedingly rapid phenomenon.

Because the pattern of the volatile acid data is similar, a close correlation between volatile acid production and gas production under conditions of normal operation is indicated. The volatile acid procedure used was a slight modification of "Volatile Acids in Digesting Sludge," as listed under the tentative tests in Standard Methods.[8] In the modification the 50-ml sample is centrifuged to remove all sludge solids and the distilling flask is protected with an asbestos ring to prevent superheating the glass above the liquid level.

Environmental Control

Similar operating results can be obtained in the full-scale installations only if a similar environmental control can be maintained in the full-scale tank. The most important factors of control appear to be solids loading, temperature control, and uniformity of distribution of sludge in the biological phase of the digestion process. If sludge is pumped so that it is transferred to the digester at substantially the same rate at which it arrives at the plant in the raw sewage, adequate control usually is provided. Wide variations in sludge volume often encountered may occur more because of inert material flushed down the sewers during wet weather flow than because of an actual variation of volatile material.

With modern external heat exchangers the control of temperature is not a problem as long as the entire

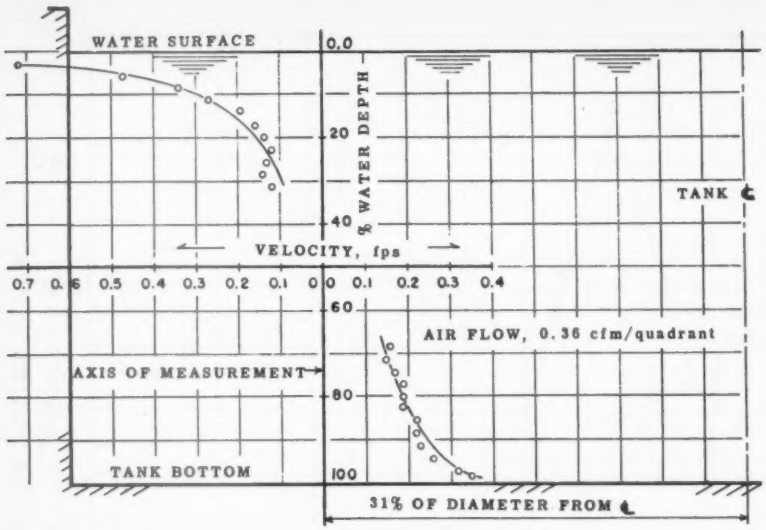

Fig. 2—TYPICAL vertical velocity profile in circulating tank.

tank contents are in circulation and therefore subject to the heating cycle.

Laboratory studies to demonstrate the uniformity of circulation of the digester contents have been carried out in a tank 4 ft square and 4 ft deep with one corner baffled so the tank was effectively one-quarter of a round tank having a 4-ft radius. Gas (actually air for this experiment) was discharged at various depths in the corner which represented the center of a full tank. Both the water depths and the depths of submergence of the point of diffusion were varied, and the horizontal circulating velocities were measured with a calibrated pygmy current meter. Vertical velocities were determined by observing the time of ascent of colored bubbles of carbon tetrachloride-benzene liquid adjusted to the specific gravity of the water. The velocity distribution is shown in Fig. 2. From the data[9] it is apparent that in a tank having a depth of 44 per cent of the diameter the top and bottom velocities are substantially equal. For example, the velocity at the 90 per cent depth is 83 per cent of the velocity at the 10 per cent depth, but in the opposite direction. At the 80 per cent depth the velocity is 120 per cent of the 20 per cent depth. Similar data were obtained for other depth-diameter ratios.

From the results of this study it was concluded that for tanks of the proportion under study the relationship between the quantity of gas diffused at the bottom center and the circulating velocities could be expressed by

$$Q = K\,V^3\,D \ldots (1)$$

in which Q is gas discharge, K is a proportionality factor, V is a representative velocity, and D is the diameter which was taken as the representative length.

Most of the velocity measurements for this study were taken at a point $D/3$ from the center and 5 per cent of the depth below the surface. Values of K were determined for both model and field conditions, which indicated that K increases with size, probably because of a decrease in importance of boundary shear with increase in size of tank. A K-value of 3.5 to 4.0 appears to give satisfactory results for conventional-size field installations.

Field confirmation of the effectiveness of circulation induced by gas lift was obtained by sampling at various depths at the Moorhead, Minn., and at the Alexandria, Minn., tanks. The solids concentrations are shown in Fig. 3 and it is apparent that except for the volume immediately below the diffusers, the entire tank contents are in circulation. Subsequent experience at these installations and at others has indicated that where sand is present it is deposited directly below the tubes. At this point it can be removed at regular intervals by gravity drainage. If not removed regularly it may accumulate in objectionable quantities, so its removal is a regular operating procedure.

The possible effect of the gas as an environmental factor other than mixing was indicated in the earlier studies[1] but was not further investigated then. Studies designed to demonstrate this effect are in progress.

Performance

Even though the solids loading and temperature are satisfactorily controlled and the digesting sludge is uniformly distributed throughout the tank, it is still necessary to have a measurement of performance to prove that the biological phase of digestion is accomplishing its purpose.

Performance can be measured both by the quantity and the quality of the final products (the gas and the digested sludge) and by environmental conditions of pH and volatile acids. From the standpoint of control of the digestion process, volatile acid concentration in the digesting sludge and gas production in cubic feet of gas pound of volatile solids added are of most interest. With uniform distribution of the solids throughout the digester these control tests have more meaning than in stratified tanks because the acid concentration represents the entire contents of the tank and not one zone where the sample was taken, and gas production reflects more directly the conversion rates of solids recently added. With digestion proceeding continuously there is no accumulation of undigested scum or pockets of undigested raw sludge which may remain dormant for some time and later undergo digestion with resulting gas production rates which are unrelated to raw sludge just previously added.

A recording gas meter is being provided for the Iowa City digester, which is being converted to allow gas diffusion, so that the rate of gas production as well as total production may be recorded. This will provide a continuous record that can be compared with the raw sludge added during each of the six daily pumping periods to give the operator an immediate indication of any change of production rates.

Determination of the volatile acid concentration in the digestion sludge serves as a check on conditions of digestion and, more important, as a check on gas production data. The laboratory and pilot plant results indicate that a major increase in volatile acids (over 1,000 ppm) is always accompanied by a reduction of gas pro-

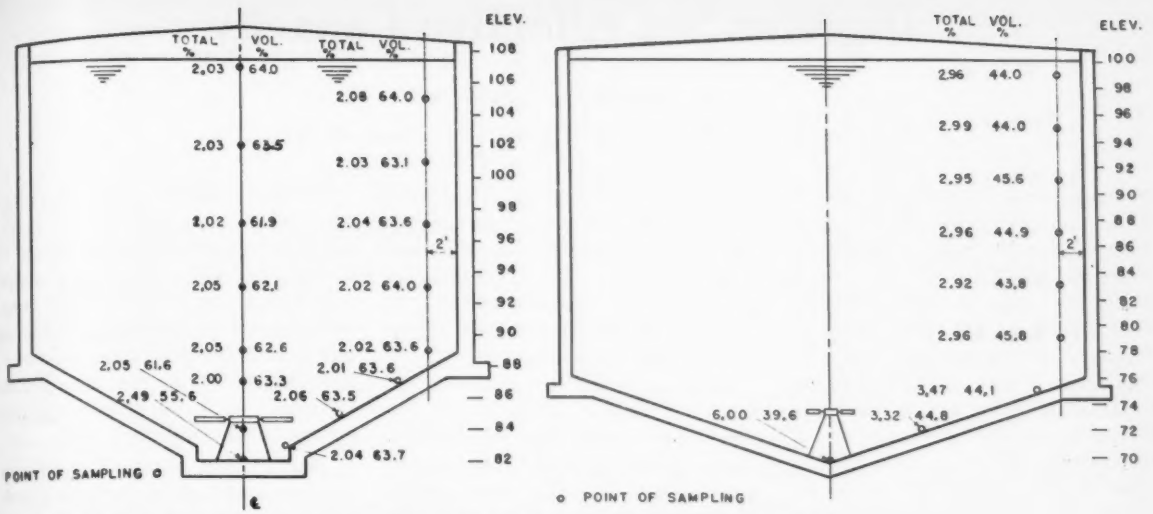

Fig. 3—SOLIDS distribution in digesters at Alexandria (left) and Moorhead (right) Minn.

duction; likewise, a reduction in gas production is accompanied by a rise in volatile acids. Thus, the operator has available a double check on digestion conditions. A deviation of one factor is cause for investigating the technique of the laboratory procedure for the volatile acid determination or the accuracy of the gas metering equipment.

Although pH generally follows variations in volatile acid concentration, it does not provide as reliable a check on gas production because of the variations of availability of the free acid and the small variations between normal and abnormal operation on the pH scale.

Use of the volatile solids content as an index of the completion of digestion is of no value alone, but the comparison of the volatile content of raw and digested sludge to get the percentage reduction is often used because it provides the most direct measurement of the quality of the final product, the digested sludge. Such an index is of value only if it truly represents the change of the sludge passing through the digester.

One method of assuring realistic data is to complete a material balance survey of the digester, including an inventory of the digester contents at the start and at the end of the test period. The input data will consist of the total wet weight, the total solids, and the volatile solids in the raw sludge and in the digester at the start of the study. The output will include similar data for the digested sludge, the supernatant liquor (if there is any) and the digester contents at the end of the test period, plus the gas produced. The period of study for such a material balance survey should be long enough so that the tank contents are displaced at least once. A longer period is preferable.

Neuspiel[10] has proposed another method of obtaining realistic data on solids reduction in anaerobic biological units where the entire tank contents are homogeneous. He has shown that in a homogeneous tank with a fixed volume and with regular and continuous solids additions, the contents at any given instant are from known solids previously added. Sixty-three per cent of the tank contents are from sludge added during the last displacement period, 23 per cent are from sludge added during the next preceding displacement period, 9 per cent are from the next preceding period, etc. Thus, 95 per cent of the entire tank contents are from the previous three displacement periods. So that the solids reduction may be computed, loading is determined for three displacement periods; the average loading is weighted according to the 9, 23 and 63 per cent proportions in the tank. A tank inventory is completed at the end of the third displacement period and the solids destroyed are simply the difference between the weighted average loading, corrected to 100 per cent and the contents at the time of the survey. Where it can be utilized, this is far simpler than the material balance survey.

Acknowledgment

The work reported herein was supported by the Chicago Pump Company and was carried on at the Iowa City sewage treatment plant. Patents assigned cover the control of the introduction of the digester gas into the body of the sludge undergoing digestion and the proper control of the interaction of the gas with the sludge.

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Digester Net Effective Capacity

by LEONARD L. LANGFORD

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In connection with the innocuous reduction of volatile, water borne solids, inimical to man's welfare, consideration should be given to a means of efficient biological reduction of such disease-ridden solids. These solids are derived from nature and require reduction in volume, as well as in putrescence, whether they are to be returned to the soil, the ocean, or the atmosphere. More specifically, consider facilities providing both a safe and flexible means for efficient anaerobic digestion of those solids susceptible to ready volatilization.

Flexibility vs Capacity

Flexibility of operation can readily be obtained by designing so as to allow for the use of any one, or all, digestion units as either primary or secondary digesters.

Equipping all tanks with floating covers or floating cover gas holders allows for substantial change in tank volume without circumventing the desirability of collecting and storing the gases of digestion under a constant positive pressure.

Capacity of digester is also of importance. But flexibility of tank volume is not to be confused with variability of tank capacity. Capacity can mean several things to several people. To the taxpayer, it can only mean the total volume for which he has to pay, or the so-called gross capacity.

Unfortunately, after some period of operation, because of mineral deposition on the bottom and a nominal trash accumulation at the top, only a portion of the total volume remains useful. This remaining portion is here referred to as the net capacity.

Further reduction of the initial or total volume is caused by the establishment of zones of sludge liquor in the upper and of concentrating sludge —buffer material—in a lower zone. This may be a normal condition in any tank. The remaining volume is here referred to as the net effective capacity. It is the most important cubage in any digester.

That the net effective capacity in any given tank is of fluctuating volume on a day-to-day basis is recognized. However, whenever the gross capacity is unreasonably reduced, because of retention of undue accumulations of sand or trash, the net capacity is adversely affected.

Likewise, whenever the net capacity is unreasonably reduced by the retention of an excess volume of supernatant and/or digested sludge, the net

ENLARGED Arlington County, Va., sewage treatment plant employs gas recirculation for improving . . .

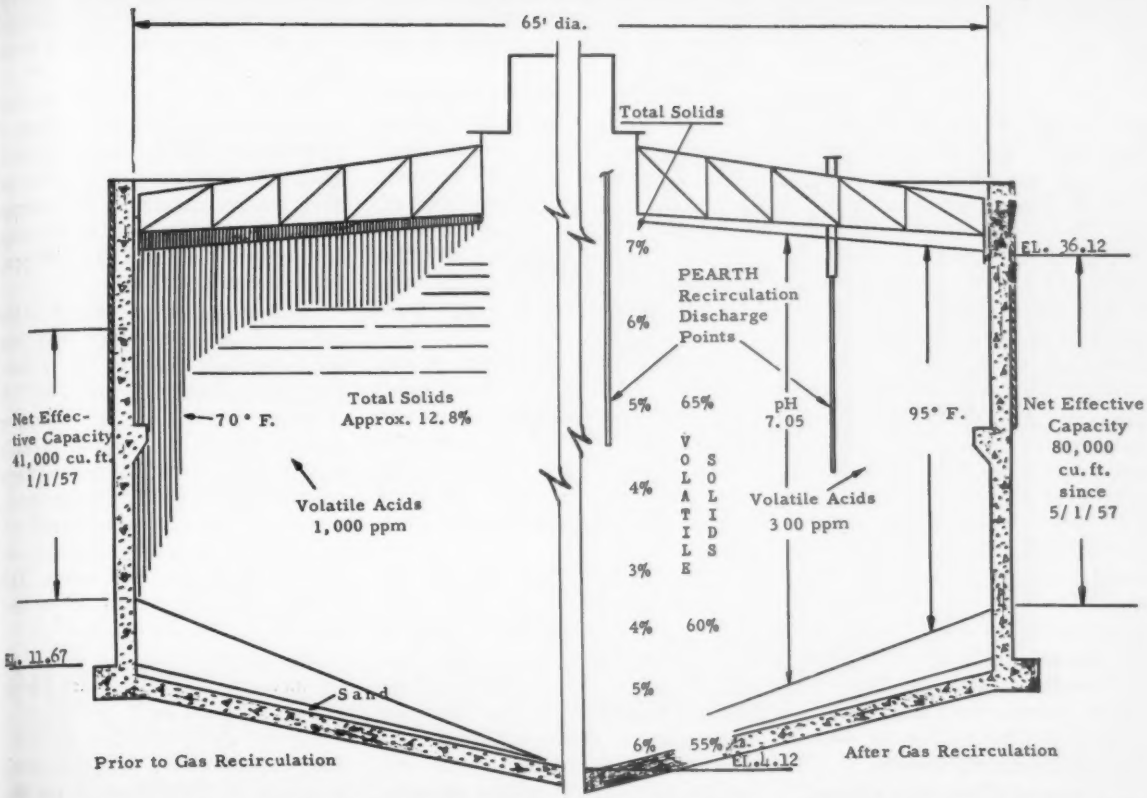


FIG. 1—CONDITIONS in primary digester No. 1 at Arlington County, Va. prior to gas recirculation are shown on the left (Jan. 1, 1957) and after gas recirculation four months later (May 1, 1957).

effective capacity is affected. Further, when the net effective capacity is reduced because of an accumulation of top or side sludge (scum), the entire digestion process may be thrown seriously out of control.

Top sludge, resulting from toxic or indigestible materials, creates an environment of relative dryness and reduced temperature not conducive to maximum bacterial activity.

Efficiency

Efficiency of digester operation, assuming adequacy of the heating facilities, can be maintained only by having complete homogeneity of the net effective capacity. A homogeneous mass will not allow for thermal stratification and trash accumulation.

Although sludge liquor circulation by pumping has been used with limited effectiveness, it is now recognized that supplemental multi-point gas recirculation is conducive to increased efficiency by eliminating gravitational stratification above the point of desired concentration of digested material.

Many operators who have the benefit of floating covers report the absence of any appreciable scum accumulation. However, these fortunate ones are possibly enjoying, to some degree, the advantages of the reaction of the air-lift principle, as the result of having a high rate of gas production per square foot of tank area.

Pearth Gas Recirculation

One of the latest contributions to the problem of reduced net effective capacity (that is, scum control) has been (a) recognizing the merit of using the air-lift principle of gas recirculation as developed by Fuhrman and associates at the Blue Plains sewage treatment plant, Washington, D. C., and (b) development of successful means for its economical accomplishment.

In 1948, at the Blue Plains plant, by means of injecting compressed sludge gas under the scum layer and into the underlying liquid zone, dispersion of a scum cap of better than 15 per cent solids, and more than 8 ft in depth, continued to a point "so that no cap as such could be measured." This point was reached after application of the Pearth process for 85 per cent of a 26-day period, with gas recirculation rate of approximately 90 cfm, in an 84-ft diameter tank with fixed cover.

Arlington Application

During 1957, the "PFT-Pearth" process, employed at the Arlington County, Va., plant, not only dissipated a top sludge blanket of 12 per cent solids and 12-ft depth, but also for about 9 months, this multipoint gas recirculation system was used to effectively homogenize the entire 30-ft depth of the digester contents.

This illustrates the flexibility of multipoint gas recirculation. In the case of Arlington County, necessity demanded that a single primary digester handle a raw solids imput of about 0.244 lb of volatile dry solids per cubic foot of net effective capacity per day. The Pearth process was therefore operated accordingly, resulting in a volatile solids reduction of better than 66 per cent in less than 15 days detention in the primary digester only.

The plant, involving primary treat-

ment and serving an area adjacent to the nation's capitol, was enlarged from the original 1937 design capacity of 5 mgd to a 20-mgd capacity in 1953.

Both the two new 65-ft diameter primary digesters, as well as the original 50-ft digesters, which were converted to secondaries, were equipped with PFT floating covers. These four tanks have a combined capacity of 278,900 cu ft. Despite occasional difficulty resulting from inhibitory wastes, these tanks operated quite satisfactorily during the first two years of service.

By the fall of 1955, the net effective capacity of the primary digesters had been drastically reduced by an accumulation of top sludge. This material of about 12 per cent solids varied from 4 ft deep in the center to 9 deep at the side wall. This blanket was composed of grease, oil, hair, and stringy rags.

By the fall of 1956, the weight of the blanket had fractured piping in both primary tanks. Also, by blocking off the recirculation suction point, the external heating system for digester No. 1 was rendered useless.

Digester efficiency was reduced to 63 per cent, on the basis of actual gas production, and emergency measures were required to maintain a bacteriological sound condition in the tank.

On January 24, 1957, with gas production less than 50 per cent of normal, and tank temperature down to about 70° F, operation of the PFT-Pearth gas recirculation process was initiated, although limited to the use of available openings in the cover, affecting only about 85 per cent of the area. By this date, the top sludge depth averaged 12 ft.

Within 7 days the heating system was restored to service. The blanket was substantially shaken down and broken up. After 16 days, digester temperature was 76° F, interior piping was no longer menaced, and about 39,000 cu ft of capacity were made useful.

In less than 30 days digester efficiency, in terms of gas production, was nearly 100 per cent; within 60 days a tank temperature of 89° F was attained. The sludge blanket had been substantially eliminated and the trash accumulation became dispersed.

For about 80 per cent of each day, sludge gas was discharged manually at the rate of 150 cfm through one or two of four discharge pipes. Except at the center, gas was discharged about 15 ft below the current elevation of the floating cover.

The homogenous condition of about 88 per cent of the gross volume of 88,000 cu ft is indicated in Figure 1, which illustrates conditions before and after gas recirculation. The average pH value of 7.05, as well as the range of volatile acids from 250 to 350 ppm, has been very constant.

Since May 1, 1957, about 11,000 gal of 4.5 per cent sludge have been fed to primary digester No. 1 daily, on a 4-hr schedule. Thus, 24,770 lb of suspended solids is fed, averaging about 0.126 lb per capita. Volatile matter in the raw sludge averages about 79 per cent or 0.10 lb per capita.

Bottom material, transferred frequently to a secondary digester, contains 50 to 55 per cent solids. This reduction of better than 66 per cent is obtained in about 12 days.

During the fiscal year 1954-5, gas production from each primary digester averaged 79,000 cu ft per day.

Present gas production from primary digester No. 1 is conservatively in excess of 160,000 cu ft per day, but cannot be measured accurately on

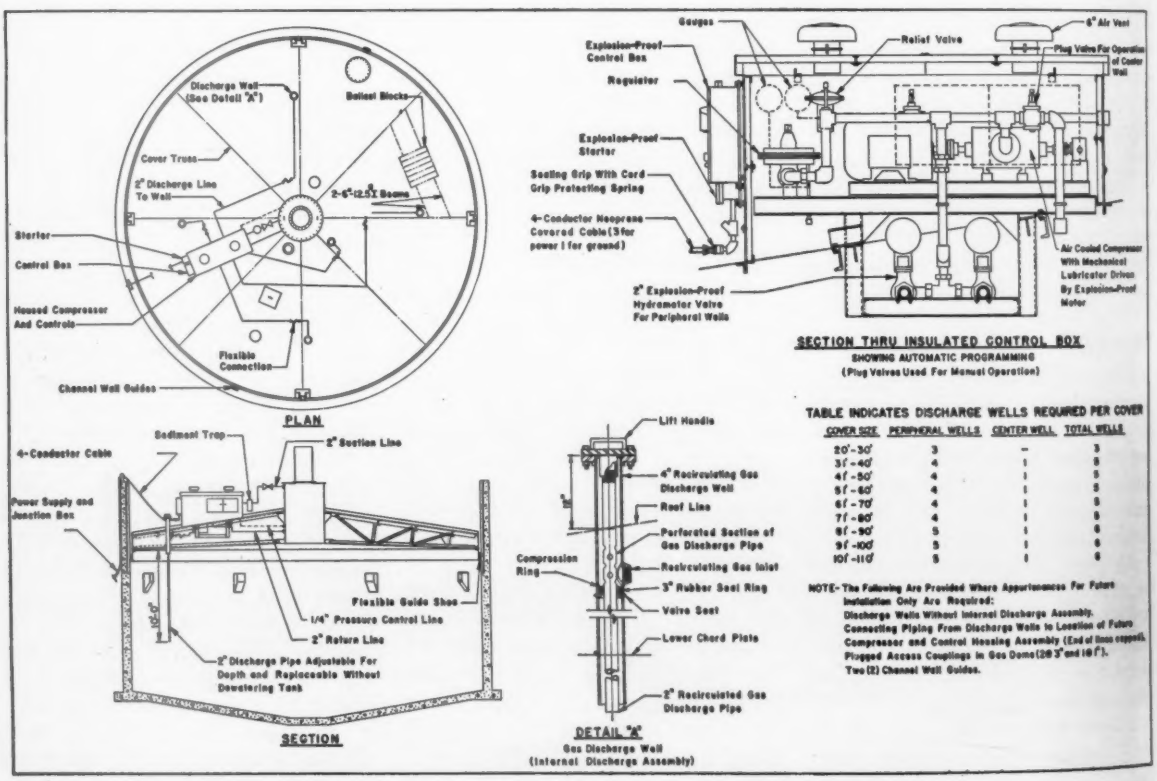


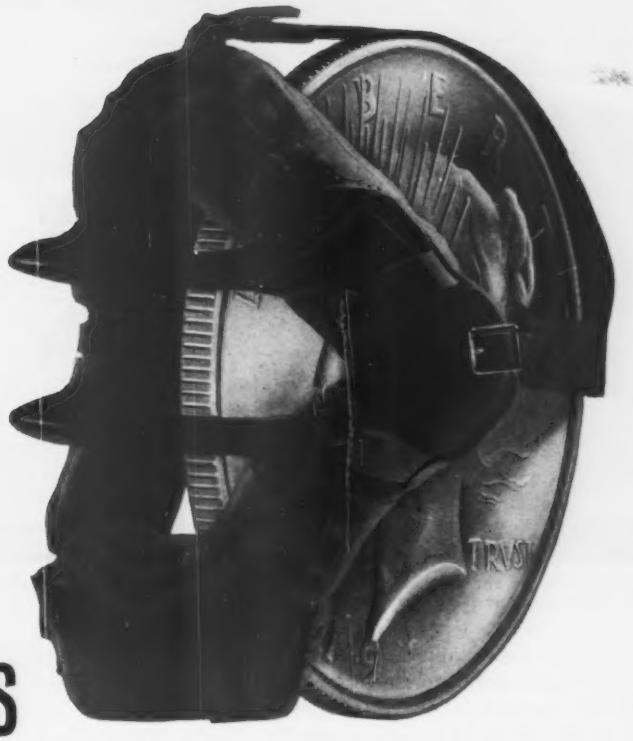
TABLE INDICATES DISCHARGE WELLS REQUIRED PER COVER

COVER SIZE	PERIPHERAL WELLS	CENTER WELL	TOTAL WELLS
20'-30'	3	–	3
31'-40'	4	1	5
41'-50'	4	1	5
51'-60'	4	1	5
61'-70'	4	1	5
71'-80'	4	1	5
81'-90'	5	1	6
91'-100'	5	1	6
101'-110'	5	1	6

NOTE- The Following Are Provided Where Appurtenances For Future Installation Only Are Required:
Discharge Wells Without Internal Discharge Assembly.
Connecting Piping From Discharge Wells to Location of Future Compressor and Control Housing Assembly (End of lines capped).
Plugged Access Couplings in Gas Dome (2@3" and 1@1").
Two (2) Channel Wall Guides.

FIG. 2—General details of the PFT-PEARTH gas recirculation system installed in Arlington County, Va.

thrifty cities protect power budgets with SUPERIOR ENGINES



More and more cities with budget-conscious administrators are wisely specifying White Superior diesel or gas engines for water, sewage treatment and power plants. They find that both fuel and maintenance costs are reduced whenever these dependable, economical engine generator sets go to work as prime power, supplementary power or standby power.

Singly or in multiples, compact, completely self-contained Superior power packages consistently produce high output for size. Diesels can operate continuously on non-premium fuel, while gas engines perform efficiently on natural, LP or free sewage gas. Because Superior has simplified engine construction to the highest degree possible—and uses only the most rugged, high quality parts—fewer replacements are required and maintenance is reduced to an absolute minimum.

White can custom-engineer Superior engines to your exact requirements and apply its extensive experience with automatic, unattended and remote control operations to your problem. If your requirements range from 215 to 2150 horsepower, or 150 to 1500 KW, call on White Superior engines to protect your power budget!

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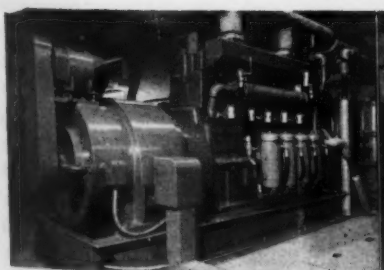
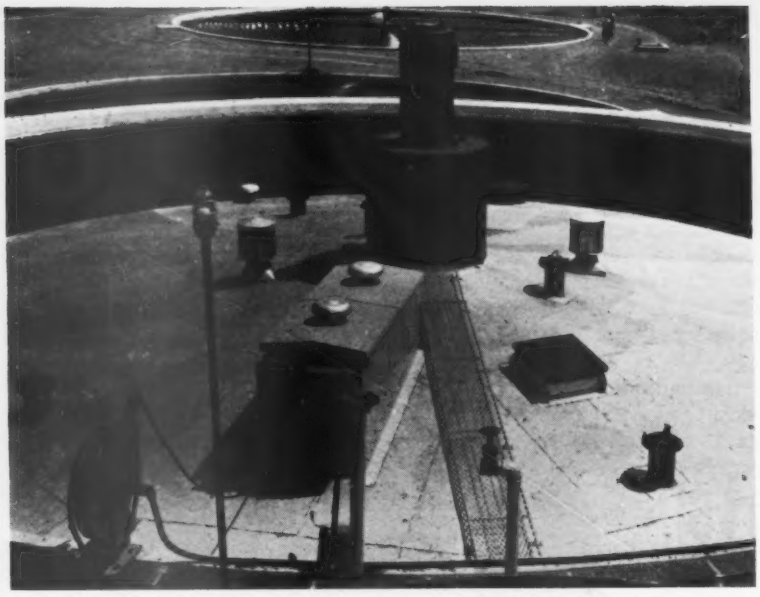


ALBUQUERQUE, NEW MEXICO . . . Superior 6G-825 gas engine generator set (250 KW) at Sewage Disposal Plant No. 1. Engine operates on sewage gas and/or natural gas.

LIMA, OHIO . . . Superior 40-SX-8 diesel engine generator set (500 KW) at city waterworks. Unit is on duty as standby power.

TUCSON, ARIZONA . . . Five Superior 80-GDSX-8 dual-fuel engine generator sets (each 1000 KW) at TRICO Electric Co-op Inc. County-wide power for farming and residential requirements.



LOCATION of control box on floating cover is indicated by this photograph of an installation at the Pimmit Run Plant in Fairfax County, Va.

account of meter limitations.

Raw solids input to digester No. 1 for the past seven months is reported to be 19,568 lb of volatile solids in 80,000 cu ft of used net effective capacity, or 0.244 lb of volatile dry solids per cubic foot per day.

Not only is the material drawn from the bottom of the tank well-digested, but also, because the Pearth process allows for gravitational stratification at the bottom, solids transferred to the secondary digesters average about 7 per cent total solids.

Other Advantages

Installation and use of this process will rejuvenate old digesters whose usefulness has become impaired by an accumulation of cold debris. The adaptibility of the system is illustrated by 50 other operating installations, where the maintenance of maximum net effective capacity, rather than high-rate digestion, is the principle requirement.

In new digesters, where adequacy of normal (natural) gas circulation cannot be foretold with certainty, multi-point gas recirculation offers, perhaps, the cheapest form of digester efficiency insurance. To facilitate obtaining such results, a compact compressor and safety relief equipment arrangement of explosion-proof design, suitably housed, has been developed (Fig. 2). Discharge well shells are designed to permit inspection or adjustment of the gas discharge lines.

Simplicity

Use of the process results in complete mixing of whatever portion of a tank it is desired to activate. The process does not require oversize gas domes; neither are porous mediums, submerged in heavy bottom sludge, necessary. There are no moving parts within the digester and the process provides safety with flexibility.

True, the theory of the air lift as a dredge pump is involved, with considerations of submergence, bubble bouyancy, expansion and slippage, as well as the specific gravity of the mixed gas and water.

Operation

Operation of the process is extremely simple. Because jets of hot, seeded sludge liquor are used in the form of hydraulicking (hydraulic mining), gas discharge pipes need only extend into the supernatant liquor layer, under the scum layer. Unless it is desired to do so, the concentrating bottom material need not be disturbed. In normal operation, power requirements are thereby reduced to the minimum.

The multiple points of application may be altered automatically or manually. Compression of gas may be required for 5 to 90 per cent of the time, as conditions dictate.

Capacity Requirements

For many years it has been generally agreed that 1 cu ft per capita was all that was required for digestion, not including the additional volume for supernatant, trash, sludge storage, and sand. This was on the basis of a plant receiving from 0.15 to 0.20 lb of total dry solids, or 0.063 to 0.084 lb volatile dry solids, per capita per day to the digester, depending on the percentage removal and other factors.

Today, with home garbage grinders and a higher standard of living, per capita removals of 0.126 to 0.168 lb volatile dry solids to the digester per day are not unusual. Even if the contribution were at the rate of 0.20 lb of volatile dry solids per capita per day to the digester, or more, it could be handled readily in an efficiently operated tank.

Referring to digestion in terms of 0.14 to 0.20 lb of volatile solids per cubic foot per day, or 1 cu ft per capita per day, amounts to the same thing.

In addition to the 1 cu ft per capita for net effective capacity, there must, of course, be added such additional volume as will be needed under the most severe conditions for supernatant liquor, for ample buffer material, and for sludge storage. This will depend largely on the method to be employed for final disposition of the sludge. Above all, there must be provided sufficient gross volume to balance uncontrollable field limitations, such as power outages, interruption of digested sludge disposal, and personnel problems, without jeopardizing a high solids reduction efficiency.

Summary

Thermal stratification frequently reduces the net effective capacity of a digester. Top and/or side sludge accumulations of reduced temperature and undesirable dryness cannot always be controlled by natural gas circulation, or by sludge liquor recirculation. Within the framework of the capacity requirements of the various state regulatory bodies, digester operation, with the tool of multi-point gas recirculation, will no longer be the difficult problem that it has been in the past. The net effective capacity can more nearly equal the capitalized gross capacity.

Sludge Gas Utilization

at Aurora, Ill.

by WILLARD P. PFEIFFER
Assistant Superintendent, Aurora, Ill., Sanitary District.

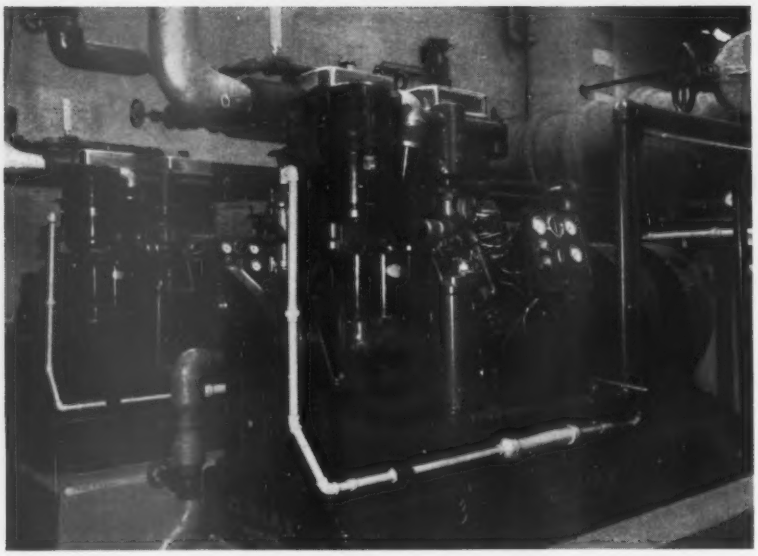
The utilization of sludge gas covers such a broad and varied field that the comments herein for the most part relate experiences at the Aurora Sanitary District's sewage treatment plant.

The digester system of a sewage plant producing gas is one function in the processing of sewage for its safe return to the receiving watercourse. Every operator must always bear in mind that the chief function of the plant in his charge is to treat the sewage through its various processes and render the effluent to the receiving watercourse as free of suspended solids and oxygen-demanding material as the facilities available in his particular plant will possibly permit.

History of Gas Utilization

Sewer gas was first obtained from sludge digestion in Exeter, England, in 1895 and burned in a street lamp. In 1902, James used gas from a septic

THESE clarified sewage pumps and engine-generator units account for the major part of the sludge gas utilized.



TWO engine-generator units, using sludge gas as fuel, supply plant light and auxiliary power requirements. Heat exchanger or engine cooling water system heats building and partially heats digesters.

tank at a leper colony near Bombay, India, for operating a gas engine. The first utilization of gas in the United States was at the Peachtree sewage plant in Atlanta, Ga., where Homman capped the gas vents of his Imhoff tanks and used the gas so collected for home heating and cooking.

The first application of sludge gas for heating a sludge tank or digester in the United States was in 1926 at Plainfield, N. J., and Antigo, Wis. In this same year gas collected at Plainfield, N. J. was used to drive two gas engines.

Since 1926 slude gas has had many uses including building heating; digester heating by the coil system; driving pumps, blowers and generators; digester heating by sludge circulation through a boiler and heat exchanger unit; incineration; gas recirculation in the digestion process; and many others. A number of plants are so arranged that they sell their surplus gas or surplus generated power to the local utilities. At Johannesburg, South Africa, and some European plants digester gas has been compressed in cylinders and utilized as truck and tractor fuel.

Volume and Composition of Gas

Factors governing the volume of gas obtained from digestion include the extent to which the sludge is digested, its character, and the available volatile matter in the raw or combined sludges.

The volume of gas to be expected may range from 0.5 to 1 cu ft per capita per day, depending on the inclusion of gas-producing industrial wastes. Inclusion of certain wastes will increase the per capita production to well beyond the 1 cu ft per day quantity.

The composition of the gas is a function of the completeness of the digestion, but will generally average about as follows:

Constituent	*Formula*	*Content*
Methane	CH_4	60 to 75%
Carbon dioxide	CO_2	35 to 20%
Hydrogen	H	Trace
Nitrogen	N	Trace
Oxygen	O	Trace
Hydrogen sulfide	H_2S	Trace
Gross heat value		550 to 750 Btu/cu ft

By comparison, the 1956 average composition of Aurora's digester gas was as follows:

Constituent	*Formula*	*Content*
Methane	CH_4	62.1%
Carbon dioxide	CO_2	32.9%
Hydrogen	H	0.3%
Nitrogen	N	0.3%
Oxygen	O	0.5%
Hydrogen sulfide	H_2S	92 ppm
		4.2 100 cu ft
		0.0009 by wt.
Heat value, gross		629 Btu/cu ft
Heat value, net		571 Btu/cu ft

The net heat value of gas is determined by deducting from the gross heat value the heat required to evaporate the water in the gas or produced during combustion.

The hydrogen sulfide content of sludge gas will vary according to the sulfates present in the raw sewage; therefore, it will reflect in part the sulfate content of the water supply of the area served. The sulfate content of the city wells in Aurora ranges from 1.6 to 8.0 grains per gallon.

Gas Purification

Prevention of corrosion of gas boilers, engines, blowers, and other equipment is a matter of great concern. Fortunately, at Aurora the amount of hydrogen sulfide contained in the sludge gas is so small that it has not created a purifying problem. If present in any quantity, however, the dry, or iron oxide, process can be used for the purpose of removing hydrogen sulfide. In this method the gas is passed through one or more boxes containing wood shavings and iron oxide, thereby converting the iron oxide to iron sulfide. The iron oxide after a time loses its effectiveness and must be renewed by exposing the exhausted iron oxide in thin layers, moistened with water and a small amount of soda ash, to the air. The iron oxide should be renewed when it has absorbed about 50 per cent by weight of sulfur.

Hazards and the Safety Problem

Care must be given to the safety features of design and operation of all gas utilizing equipment.

Journals and magazines dealing with water, sewage and industrial wastes have carried extensive articles on the explosions that have occurred from sludge gas. Sludge gas explosion hazard will exist when there is a mixture in the ratio of 1 part of gas to 7 to 10 parts of air. Every operator should have in his library Manual of Practice No. 1 entitled, "Occupational Hazards in the Operation of Sewage Works," published by the Federation of Sewage and Industrial Wastes Associations. *Waterworks and Sewerage* in September 1941 carried an article "Elimination of Gas Hazards at Sewage Treatment Plants," which covers this problem rather completely.

All gas collecting systems should be positively sealed tight. Furthermore, all buildings and galleries where

gas is collected or may collect should be adequately vented by forced-draft fans.

Purging of all gas collecting and distribution lines after repair or maintenance is definitely good practice. Likewise, when and if it becomes necessary to work on the inside of a discharged digester, proper purging with forced air is definitely a "must."

Flame traps should be provided on all gas burning equipment. It is advisable to occasionally check the flame trap for its proper functioning and follow this by removing the wire gauze and cleaning it. A supply of fusible links and accessories should be maintained at all times.

Pressure relief and reducing valves, although reliable, need periodic inspection for their continued dependable service. All diaphragms on relief valves should be vented to the outside atmosphere.

Although not essential, at Aurora it has been found that by providing a by-pass line around the sludge gas meters uninterrupted service is accomplished when it becomes necessary to remove the meter for repair or replacement and air is prevented from entering the system during this operation.

Hydrogen sulfide, which has a rotten egg odor, is one of the minor components of sludge gas; but it is fatal in 30 minutes or less at concentrations of 0.06 to 0.10 per cent, and will cause severe illness at concentrations 0.05 to 0.07 per cent. Concentration of hydrogen sulfide greater than 2,000 ppm (0.2 per cent).

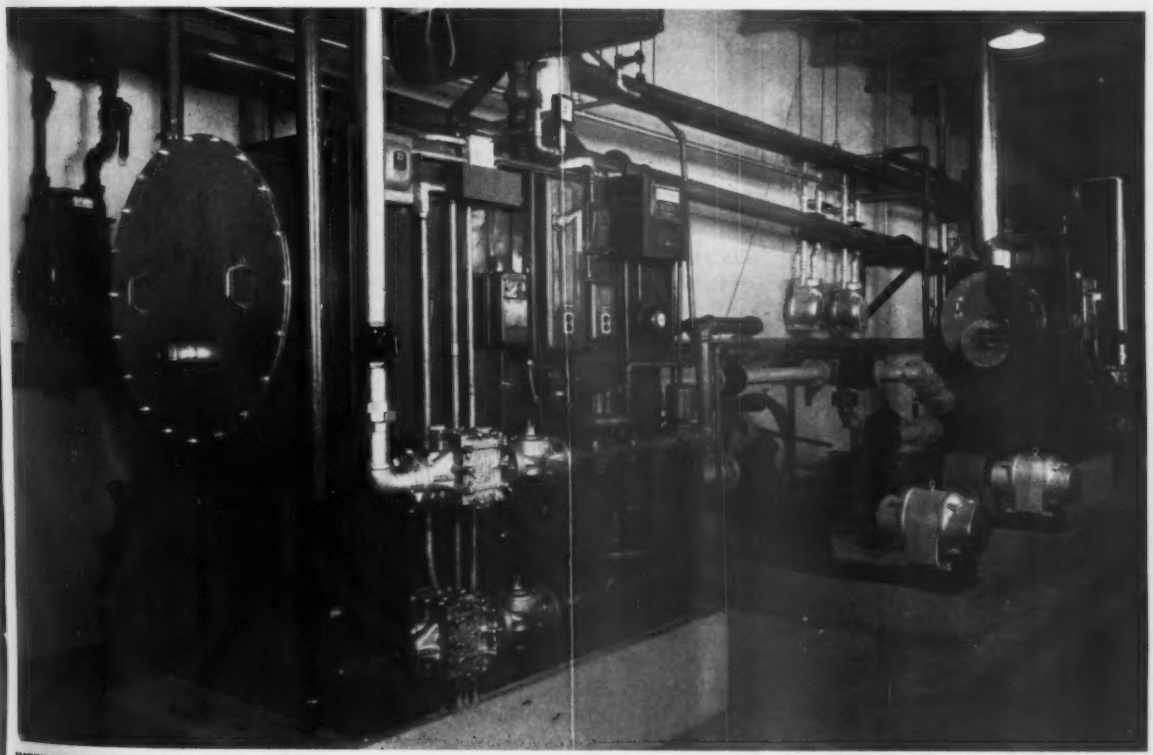
Filter paper in ½-in. wide strips immersed in a lead acetate solution (10 per cent) and allowed to dry provides the operator with a quick method for detection of hydrogen sulfide. The filter paper is placed in the area under observation and in the presence of hydrogen sulfide will change to a brown-black color.

Collection of Sludge Gas

As long as the collecting and distribution system is under positive pressure no air can enter the system to produce an air-gas mixture and no hazard will result.

On outside digester gas lines it is well to insulate the lines with frostproof-type insulation in order to keep the gas coming off the digester at or near the digester temperature, thus avoiding condensation in the collecting system. Some difficulty was experienced at Aurora in placing new sludge gas meters in an enclosed room, about 35 ft from the gas collecting dome, and provided with drip traps preceding the meters. The amount of condensate in the collecting system was sufficient to partially fill the meter chambers, and occasionally to cause them to run backwards. This problem was solved by repositioning the meters in the control room housing the sludge heat exchanger units, where it is quite warm. Condensation problems in sludge gas collecting lines are a matter of controlling the dewpoint. More favorable conditions are present for dewpoint control when the temperature of the gas released from the digester is less than that of the surrounding air. Conversely, when the sludge gas temperature in the gas released from the digester exceeds that of the surrounding air dewpoint problems arise or are increased.

In addition to the drip trap and check valve installed near the gas dome, a dogleg drip trap was provided on the inlet side of the meters to further collect the condensation formed. This solved this problem. Experience



INTERCONNECTED external heat exchangers using sludge gas as fuel maintain two new first-stage digesters at optimum temperature automatically.

after 20 months of operation indicated that the greater portion of the condensation was removed at the drip trap and check valve near the gas dome. Condensation is removed from all gas collecting meters on every 8-hr shift, and oftener if necessary. On all gas collecting meters pet cocks or valves have been installed to drain the bellows system in the meter chambers. The life of the gas meters and the collecting system can be prolonged if the condensation problem is adequately recognized.

Through Aurora's experience with gas collection it has definitely been concluded that the installation of cleanouts in the gas lines from the digester to the distribution header provides for a reasonable way of cleaning of the iron sulfide scale on the pipe interior. Cautious pounding of the pipe system, followed by flushing with water, will remove the bulk of the scale. Once this is accomplished the collecting system should be adequately purged to discharge air that has entered the collecting lines during these operations.

Among the never-ending maintenance requirements of a sewage treatment plant is periodic inspection of the check valves in the gas collecting system. The drip pots and gas seals must likewise be included in this maintenance program.

Two of the gas meters serving the secondary digesters at Aurora are installed in the digester house not far removed from the gas dome and subjected to almost outside temperature conditions. Condensation was not sufficiently collected in the drip trap, with the result that a portion of the condensate found its way into the meter chambers. After various solutions were suggested to prevent this condition, the matter was solved by building around these two gas meters a Celotex room, with inspection doors, and providing a number of heat lamps to keep the room at a temperature sufficiently high to prevent an appreciable amount of condensation within the meter body. This has proved very effective in condensation control.

Waste Gas and Gas Storage

The function of the waste gas burner is to burn the excess gas to the atmosphere to prevent possible hydrogen sulfide odor. There are many forms of the waste gas burner available; or an operator can design and fabricate his own burner to meet his specific needs. Such a burner should be placed in a well-protected area and removed from other gas utilizing equipment.

Because sludge gas production at times is at an irregular rate, it is necessary to provide some form of storage tank that will act as a reservoir between the supply and the demand of plant equipment. Three forms of storage in use are: (a) the dry-seal gasometer, (b) the floating reservoir, and (c) the pressure holder. At Aurora, pressure storage provides 11,000 cu ft of gas at atmospheric conditions.

Gas Utilization Equipment at Aurora

The sewage treatment plant at Aurora is of the separate sludge digestion type. Originally, in 1929, sludge digestion capacity was 120,000 cu ft, but this was increased to 200,000 cu ft in 1956. The estimated population now served is 65,000. The average daily flow handled by the plant in 1956 was 8.770 mgd.

COMPRESSOR used to transfer sludge gas from low-pressure distribution header to high-pressure (65 psi) storage tanks.

The first use of sludge gas at Aurora was in the interconnected low-pressure boilers providing building heat, the heating of approximately 140,000 gal of water per day in the digester coil system of the then three digesters, and for miscellaneous purposes in the plant laboratory. Temperatures in the boilers were maintained below 160°F to avoid lime scale deposits in the circulating coil system. The boilers were provided with the then conventional automatic and protective controls.

After installation of the sludge gas pump and generator engines, the use of digester gas in the low-pressure boilers was decreased due to the 60 per cent, or more, of heat recovered in the exhaust heat exchanger. From 1936 on, the boilers were only used to provide supplemental heat, as required, for sufficient building heat and optimum digester temperatures.

In 1953, natural gas became available in the plant area for process work. At that time the boilers, which had previously been interconnected, were separated so as to provide one boiler for building heat on digester gas and the other boiler for digester heating and screenings incineration on either digester or natural gas. This digester hot water heating boiler was then provided with two sets of burner orifices so that one-half of the boiler could be operated on sludge gas while the other half was operated on natural gas.

In 1931 a Midwest incinerator was installed in the screen house to incinerate screenings removed from the raw sewage and the grease and scum skimmed from the four clarifiers. This incinerator was designed to burn not less than 1 cu ft of screenings and 1 cu ft of grease and scum per hour, with stack gases above 1,500°F to be free from objectionable odor. Gas consumption was not to exceed 7,000 cu ft of sludge gas per 24 hr with a Btu content of not less than 500, for the burning of screenings having a moisture content of about 80 per cent and grease and scum with a moisture content of about 60 per cent. Explosion dangers through the failure of gas pressure were eliminated by installation of an automatic gas shut-off valve in the supply line.

Experience with this incinerator has been satisfactory. It removed the problems of screenings burial and the disposal of grease and scum accumulations from the clarifiers, and removed the possibility of odor problems in the neighborhood. This incinerator is still in service, although incineration of grease and scum has been abandoned in favor of digestion in the digesters. In 1953, when natural gas was made available to the plant, the incinerator was equipped to operate on the natural gas supply.

In 1934, a LeRoi 11-hp, 4-cylinder, stationary sludge gas engine direct-connected to an Aurora 4-in. centrifugal pump was purchased to be used for the dewatering of the clarifiers

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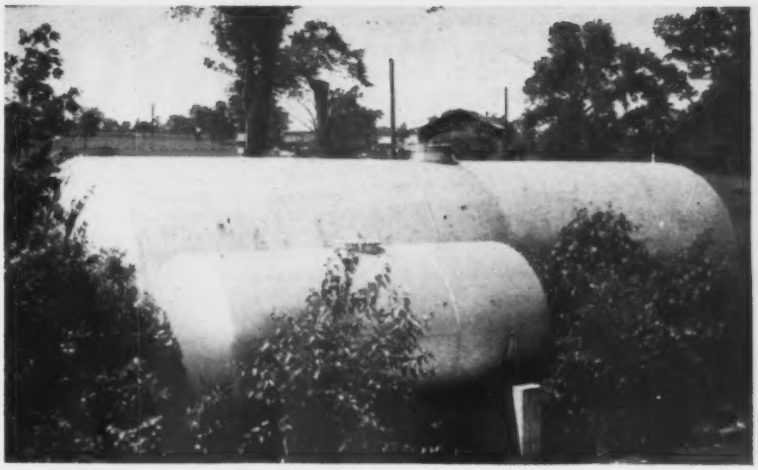
and filling digesters with raw sewage after they had been discharged to the drying beds. This gave another use for the by-product of digestion. The engine was used only intermittantly under the plant operating conditions, but it served the plant effectively until 1955, when the gas engine was replaced with a used 10-hp electric motor as being, at that time, better adapted due to the problems encountered in starting the gas engine for infrequent use.

During this same year a second Le-Roi 11-hp 4-cylinder, portable gasoline engine direct-connected to a 4-in. centrifugal pump was used for dewatering operations throughout the plant. It became necessary to dewater one of the settling tanks of the secondary unit for repairs. The idea of trying to operate this gasoline engine on sewer gas was considered and eventually such a project was undertaken by installing the carburetor of the sludge gas engine on the gasoline engine unit. A garden hose was attached to the sludge gas supply line in the secondary pumphouse building and connected into the carburetor system. The engine performed without difficulty and this new adventure on sewer gas use saved approximately 100 gal of gasoline on this one operation alone.

Pump Engines

The plant is located about 5 miles downstream from Aurora on Fox River. No pumping of raw sewage is necessary; practically all of the flow is brought by gravity to the screen house for treatment. Clarified sewage must, however, be lifted about 27 ft to the dosing chambers of the sprinkling filters. From the beginning of operation in 1929 this was accomplished by lifting the clarified sewage with one of two 75-hp motors attached to 8-mgd centrifugal pumps. In addition there was provided a 50-hp motor connected to a 6-mgd centrifugal pump for stand-by service.

In March 1936 the two electric motors were replaced with two Climax 75-hp, 6-cylinder, low-speed (550-800 rpm) gas engines direct-connected through flexible couplings to the existing 8-mgd pumps. The engines are equipped with the usual air filters, oil filters, and safety devices to protect the engines from overheating and loss of oil pressure. The gas supply system is protected by flame traps and pressure relief valves. Gas storage facilities were provided to help bridge low production periods from the digesters. Sludge gas is taken from the distribution header and passed through a small surge tank before compressing it from about 10-in. water column pressure to a maximum of 65 psi in the storage tank. The system is provided with a muffler system for noise control. Although the storage facilities of but 11,000 cu ft of gas at atmospheric conditions is small, inclusion of this storage tank has been more than worthwhile in bridging many low gas production periods for the continuous operation of both the pump and generator engines.



STORAGE tanks provide only 11,000 cu ft at atmospheric pressure, but hold over most low gas production periods.

The speed of the engine is controlled by a float-operated mechanism operating over a drum attached to the governor of the engine, which increases the engine speed on a rising wet well level and decrease it on a receding level in the well.

Exhaust temperatures from the engine system ran around 800° to 950°F. Exhaust gases originally first passed through a muffler system and then were directed through the exhaust heat exchanger to radiate heat to the digester water circulating through the heat exchange. This provided a recovery of about 60 per cent of the heat supplied to the pump engines.

After several years of operation the muffler system was discarded to provide higher exhaust temperatures to the exchanger in the hopes that this would tend to prolong the life of the wrought iron tubes in the exchanger due to corrosion in the tubes when the temperatures were below the theoretical dewpoint of 130°F. The average life of the wrought iron tubes in the exchanger was about 4½ to 5 years before replacement was necessary. Within the last two years the design of the exhaust heat exchanger was modified so that the exchanger was shortened by 4 ft. This results in a more uniform exhaust temperature through the unit, averaging well above 200° F and far above the theoretical 130° dewpoint for the elimination of corrosion. At this time the unit was re-tubed with stainless steel tubes. So far this change has given no trouble and the additional cost of the stainless steel tubes seems well justified.

Data from the 1956 Annual Report of the District give an over-all picture of operations with these two pump engines from April 1, 1936, to January 1, 1957 as follows:

Operation time, total, hr	164,124
Operation time, % of poss	90.2
Power devel., total, hp-hr	7,110,071
Power devel., avg, hp-hr	43.31
Avg % of rated hp (75)	57.75
Pumpage, total, mil gal	46,546.58
Pumpage, avg, mgd	6,850
Sludge gas used, total, cu ft	127,603,100
Sludge gas used, avg, cu ft day	18,600
Gasoline used, total, gal	27,328
Nat. gas used, total, cu ft	2,743,900
Equiv. sludge gas, cu ft	4,346,000
Gas used per hp-hr, cu ft	17.95
Avg heat value of gas, Btu	583
Avg Btu per hp-hr	10,500
Motor oil used, gal	1,870
Total maint. cost (incl. gasoline, natural gas and motor oil)	$25,987.50

The gross savings in pumping costs for this period, based on the prevailing power costs, amounted to $89,792.92. Repairs, maintenance, oil, gasoline, natural gas, and stand-by power for operating the 6-mgd low-lift centrifugal pump for this same period amounted to $30,074.79. The net saving in pumping costs for this 249-month period was $59,536.13, or a return of 703 per cent on the net investment in this pump engine installation cost of $8,521.50.

Generator Engines

The gas production history and experience with the gas pump engine units installed in 1936 were so favorable that in November 1940 two 50-hp, 4-cylinder, 720-rpm Climax gas engines, direct-connected to two Electric Machinery 35-kw, 440-v, 60-cycle, 3-phase, synchronous generators were installed with the necessary automatic synchronizing switchboards and safety equipment. These generators were to provide all power and light for the 27 or more auxiliary motors in operation at the plant. At this time all outside power connections were severed with the local utility and the plant was "on it own."

Having the generator engines of the same type and piston size as the pump engines provided the advantage of interchangeable parts on these engines. The generator engines were air-start, dual-magnetoed for the 12-v ignition system. They use either sludge gas or gasoline, or both. The engines, like the pump engines, are operated continuously and alternated every other week. The dependability of these generator engines is evidenced by the fact that they have been in operation for 99.57 per cent of the total elapsed time since their installation. Experience with this equipment has been more than favorable, with maintenance and repair costs nothing more than the normal expectancies of any mechanical and electrical equipment.

The low hydrogen sulfide content of the Aurora sludge has not created any corrosion problem within the engines.

Data from the 1956 Annual Report give an over-all picture of operation of these two generator engines from November 1, 1940, to January 1, 1957, as follows:

Operation time, total, hr	141,114
Operation time, % of poss	99.57
Power produced, kw-hr:	
Power	1,388,275
Lights	270,321
Total	1,658,596
Power devel., total, hp-hr	2,777,989
Power devel., avg, hp-hr	19.70
Avg % of rated hp (50)	39.4
Power devel., avg, km-hr/day	282
Sludge gas used, cu ft:	
Total	70,337,600
Per day	11,960
Per kw-hr	42.5
Per hp-hr	25.3
Avg Btu per hp-hr	14,820
Avg Btu per kw-hr	24,725
Gasoline used, total, gal	4,786
Equiv. to sludge gas, cu ft	991,500
Motor oil used, gal	1,468.5
Total maint. cost (incl. repairs, gasoline and motor oil)	$13,215.18

WASTE gas burner on office and laboratory building roof.

During the 193 months of generator operation they were out of service only 606 hr, or 0.43 per cent of the total elapsed time. The generator engines and appurtenances were installed at a cost of $9,800. Gross saving for this period has amounted to $36,433.12 based on the prevailing power and light rates. Maintenance, repairs, oil, and gasoline charges for this same period totaled $13,215.18, producing a net saving of $23,217.94 in power and light cost for this 193-period. This has produced a net savings equivalent to a 236 per cent return to the District on this engine-generator investment.

Natural Gas

The available digester gas in the pressure storage tank has not always been sufficient to bridge the low gas production periods. Therefore, it became necessary to operate either the pump engines or the generator engines on the auxiliary gasoline fuel during these periods. Gasoline operation was rather expensive, produced a diluting effect on the crankcase oil, and left the engine not as clean internally as under the normal gas operation.

When natural gas was made available in the plant area for pumping purposes, a study revealed that a considerable saving was to be had by providing the plant with natural gas for pumping the clarified sewage to the filters by the two 8-mgd pumps during periods when sludge gas production was inadequate for this operation. In 1953 a natural gas line was run into the plant for this purpose; no appreciable use of gasoline as a fuel for the pump engines has been made since then.

At present, it is understood that natural gas is available in the plant area for power generation. Under current plant operating conditions and anticipated increase in digester gas production it is assumed that the use of natural gas as fuel for power generation will not be considered at present.

External Sludge Heater

With the constantly increasing solids load being imposed on the treatment plant by the fast growing limits of the Aurora Sanitary District and the anticipated building boom, it was evident that the digester system was overloaded and needed additional capacity. Consequently, in 1956 two additional first-stage digesters were installed. With this addition the total digester capacity was increased to 200,000 cu ft.

In conjunction with the additional digesters two Walker external heat exchanger units were installed. Each unit consists of a 500,000-Btu per hr boiler, a 500,000-Btu per hr heat exchanger, and a 250-gpm 4- by 4-in. non-clog pump for circulating digester sludge through the exchanger to the digester. The necessary electrical and gas control safety features were provided in these units for the safe operation of all equipment installed. Piping was so aranged that either unit can supply heat to either of the two new digesters.

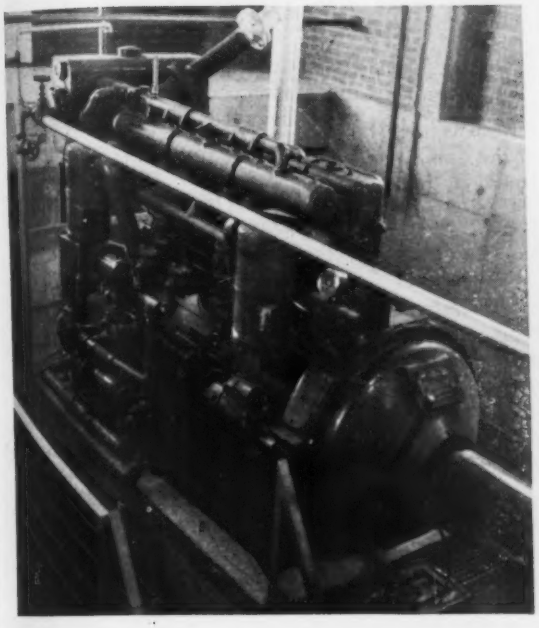
In addition, one of the digesters was equipped with 800 ft of 1¼-in. wrought iron internal heating coils. The advantage gained in this arrangement was that surplus heat from the

ROILINE ENGINES (Formerly LE ROI)

POWER FOR MUNICIPAL PLANTS

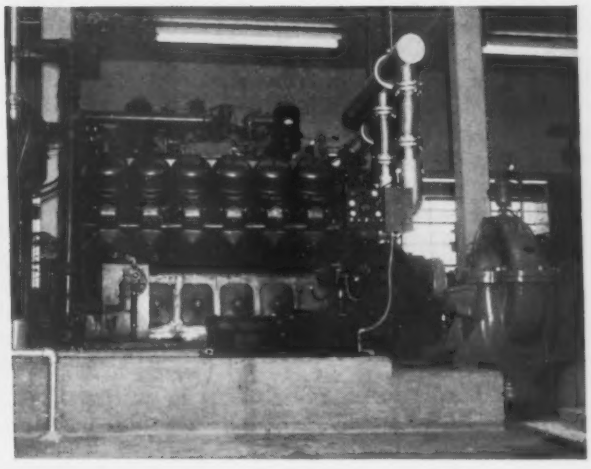
* The trade mark LE ROI is used under license from Westinghouse Airbrake Co., the trade mark owner.

Three ROILINES pull the pumps at Oklahoma City's Lake Hefner Municipal Filtration Plant.



Model F-1500, maximum horsepower 215 at 1200 rpm on natural gas.

Model L-3460, maximum horsepower 595 at 1350 rpm on natural gas.



BASIC ENGINE CHARACTERISTICS*

GASOLINE OR NATURAL GAS					600	800	1000	1200	1400	1600	1800	2000	2200	2400
MODEL	Bore & S.	Cyls.	Displ.	Torque–rpm	BRAKE HORSEPOWER AT ENGINE SPEEDS INDICATED									
H540	4½ x 4¼	8	540	430- 900	...	64	82	99	115	130	143	155	164	170
H844	5¼ x 4⅞	8	844	637-1500	...	106	135	165	191	215	237	255	270	278
F1500	6¾ x 7	6	1503	1090- 650	125	165	200	215						
H2000	6¾ x 7	8	2004	1485- 650	170	225	270	290						
L3000	6¾ x 7	12	3006	2200- 650	250	335	405	435						
L3460	7¼ x 7	12	3468	2570- 900	285	391	492	568	595 @ 1350 RPM					
L4000	7.54 x 7.5	12	4000	2930- 900	325	446	560	645						

*With oil pump, water pump, magneto, air cleaner, carburetor, and exhaust muffler. Hp shown is maximum.

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OKLAHOMA, Chickasha, Chickasha Gin & Mill Supplies
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TEXAS, Houston 1, Southern Engine & Pump Co. (also in Beaumont, Corpus Christi, Dallas, Edinburg, Kilgore, San Antonio)
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heat exchanger of the pump and generator system was utilized to help maintain optimum temperature conditions within this digester and at the same time conserve the use of sludge gas in the operation of the heat exchanger system. At the same time it was possible to keep the engine jacket water temperature below 190°F, particularly during the summer months. Previous to this installation the excess engine water heat had to be dissipated by passing a portion of the engine water through a submerged coil system in the clarifier influent channel when the engine circulating water temperature approached 200°.

The heat exchanger units are provided with both natural and digester gas supply and with individual metering facilities.

Boiler water temperatures have been controlled at about 190° and the blending water for the exchanger tubes at about 130°. With these temperatures it has been possible to maintain a 6° to 8° sludge temperature differential through the heat exchanger. Digester temperatures are maintained at slightly above 90°.

Practically no difficulty has been experienced from clogging or overheating of the circulating sludge pumps. There have been no stoppages within the tube system of the exchanger.

After approximately 15 months of operation the results have been more than gratifying. Digester temperatures have been maintained above 90° and at a more uniform temperature. Circulation of sludge in the digester has been maintained at the rate of 2.5 hr on each 8-hr working shift. This provides a complete turnover of the digester in about 2.6 days. Under this system the circulation time may automatically be extended if the digester requires more heat. During this 15-month period the No. 1 heating unit has consumed an average of 8,300 cu ft of digester gas and 1,100 cu ft of natural gas per day to maintain the optimum temperature in the digester. In the No. 2 digester heater, where a portion of the heat needed for the sludge is supplied from the heat recovery system of the pump and generator engine exchanger, only an average of 1,700 cu ft of digester gas and 100 cu ft of natural gas has been used daily.

Gas Lifts

After considerable study, a gas circulating system was installed in one of the first-stage digesters early in October 1957. This provides the sewage plant with another use of sludge gas in the operation of the digesters. Not only is this Walker unit to increase gas production and provide a more uniform solids content within the entire digester, but also the operating and general results of this new venture will be of great interest for future expansion planning.

Aurora's Gas Production

Based on the 1956 daily average of 11,000 lb of primary sludge and 890 lb of secondary sludge removed for digestion, the digesters produced 48,210 cu ft of 629-Btu (gross) sludge gas. The daily use distribution of this quantity of sewer gas was as follows:

Digester and building heat	4,100 cf	8.5%
Pump engines 1 and 2	19,690 cf	40.9%
Generator engines 3 and 4	13,480 cf	28.0%
Incinerator	3,740 cf	7.7%
Heat-X units 1 and 2	4,040 cf	8.4%
Wasted	3,160 cf	6.5%
Total	48,210 cf	100.0%

The average daily sludge gas needed to maintain complete operation of the gas-utilizing equipment at Aurora totals 51,100 cu ft. The average daily deficiency of sewer gas was 2,890 cu ft, which was provided by the natural gas supply available at the plant. Therefore, in 1956 the digester system provided 94.2 per cent of the plant's total sludge gas requirements.

The utilization of 17,646,600 cu ft of sludge gas in 1956 had a value of $7,917 based on current natural gas rates. In breaking this down to a daily basis of 48,210 cu ft, this sludge gas was worth $21.70 to the plant in its operation. The sludge gas produced from digestion is definitely a by-product of sewage treatment that can help to increase efficiencies in sewage treatment and assist in reducing operating costs.

DEWATERING, DRYING AND INCINERATION

DIGESTED sludge (and raw sludge, as well as secondary sludge) contains a large amount of free water and in general cannot be disposed of until this free water is removed. (One exception is direct application of liquid digested sludge to farm land.) Therefore, the sludge must be dewatered before the final step in disposal. Dewatering may be accomplished on sand beds, by chemical coagulation and vacuum filtration, lagooning, and, in the case of raw sludge, by flotation through biological activity followed by filtration.

Sand beds or sludge drying beds are level areas of underdrained sand upon which the wet sludge is applied to a depth depending on the kind and character of the sludge. The applied sludge drains and dries with a rapidity depending upon the weather conditions and the character of the sludge. The "dried" sludge reaches a moisture content of 50 to 60 per cent, shrinks about 65 per cent in bulk and is spadable after ten days to three weeks. Freezing and thawing, and rain add to the speed with which water-binding colloids are removed from the sludge and hastens its dewatering, but where adverse winter conditions exist, covering of the beds with glass-roofed "greenhouses" makes it possible to carry on operations all year. The area of sand beds required may vary from about 0.5 to 2.0 sq ft per capita, depending on many factors. Most sand drying beds are used in conjunction with Imhoff tank installations or small plants where mechanical dewatering is too expensive.

Chemical Conditioning

Sludge conditioning or coagulation with chemicals is essential to the effective utilization of vacuum filters as a means of dewatering sludge. Upon the addition of conditioning chemicals, the colloidal matter in the sludge is "shrunk" and its water released so that it may be filtered. For raw, digested and chemical precipitated sludges, the common coagulants are ferric chloride and lime although aluminum chloride, and aluminum sulfates have been used with lime. For digested sludges the chemical consumption averages 2 to 3 per cent ferric chloride and 6 to 10 per cent lime (CaO). Raw sludge requires less chemicals; 1.3 to 1.5 per cent ferric chloride and 3.5 to 4.0 per cent lime. Activated sludges can be conditioned with ferric chloride alone, with 3 to 4 per cent of chemical. (All percentages are based on pounds of dry chemical to pounds of dry sludge solids.)

Elutriation

Elutriation is a process for the "washing" of digested sludge by passing the sludge counter current through a flow of clear water or sewage effluent. In this manner, decomposition products of digestion, particularly ammonium bicarbonate, are washed out of the sludge. Thus the alkalinity of the sludge is reduced and therefore less lime will be required for conditioning since much of the lime used reacts with the bicarbonate alkalinity. Elutriation also removes those chemical products which tend to stabilize the colloidal nature of the sludge. With the removal of these "peptizing" substances, the sludge can be coagulated more easily. The process was originated by A. L. Genter and has been installed at a number of plants throughout the country. Elutriated sludge requires little if any lime and only about 35 per cent as much ferric chloride as unelutriated digested sludge.

Vacuum Filtration

Vacuum Filters generally are drums which rotate on a horizontal axis, partly submerged in a tub of conditioned sludge. The deck of the drum is covered with a wire mesh or other solid covering over which is laid a covering of filter cloth. Wool cloth is used when lime is not used for conditioning, cotton cloth where lime is used. Synthetic cloths are also used. Vacuum is applied inside the drum for about five sixths of its rotation. Sludge particles are sucked against the cloth and form a cake. During rotation the free water is removed from the solids and discharged through a pump to the raw sewage influent. This liquid is clear and relatively free of B.O.D. and amounts to about 80 per cent of the volume of the digested sludge treated.

Before the filter drum completes its revolution the vacuum is cut off and air pressure applied to remove the cake from the filter cloth. A doctor blade is used to help remove the cake. On some filters a string discharge is used in place of air pressure and doctor blade, the strings which lie against the filter cloth for most of the revolution of the drum then leave the drum, after the vacuum is released, and pass over a separate roller at which point the sludge cake is discharged.

A variation of the string vacuum filter is the Komline-Sanderson Coiled Spring Filter. This filter is constructed with stainless steel decking over which two layers of coiled springs (like cords) are laid down in overlapping positions by means of rotating grooved cylinders. Vacuum is applied for 50 per cent of rotation, and the filtrate passes between and through the coils, which discharge over a roller and then are washed before returning to position.

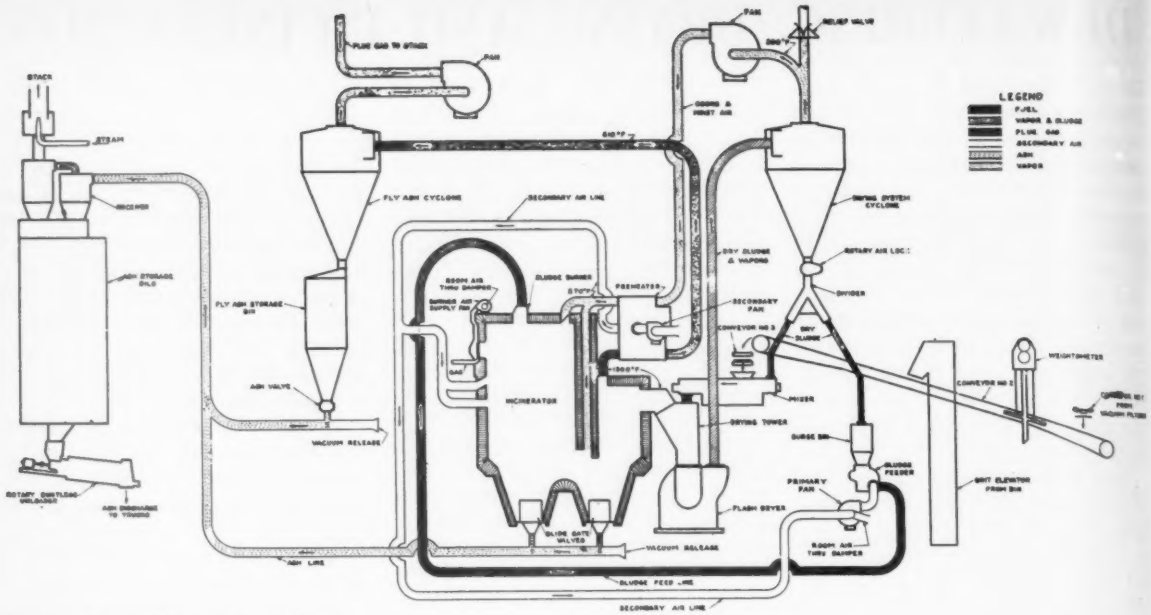
The weight of the sludge cake removed may be determined from any filter by discharging the sludge cake onto a moving conveyor belt fitted with a device for continuously weighing and integrating the weight of the sludge on the moving belt.

Flotation

Biological flotation is a process for the thickening of raw sludge without chemicals and conditioning it for ease of dewatering on vacuum filters. Experimental work of the Allegheny County Sanitary Authority at Pittsburgh, Pa., before construction of the plant indicated that at 20 to 35 deg. C., a period of approximately five days produced an acid fermentation and the formation of carbon dioxide bubbles which floated sludge solids to the surface of the tank from which they could easily be removed to vacuum filters. Raw primary sedimentation tank sludge of 5 to 8 per cent solids was thus concentrated to a solids concentration of 14 to 20 per cent. Subnatant liquor is clear and can be returned to the raw sewage. The solids are easily filtered to decrease the moisture content.

Drying and Incineration

In small installations, wet sludge cake may be hauled away to a fill,



FLASH drying and Incineration System

but in large plants, the cake may be dried (and used for fertilizer) or incinerated. Dryers of several types are available: Double-Shell, semi-direct heat. Louisville rotary, rotary louvre, atomizing, and flash dryers.

Incinerators are of two principal types, Raymond Flash Dryer system (Combustion Engineering) and the Multiple Hearth system (Nichols-Engineering and Morse-Boulger).

The Flash drying system dries and burns the sludge in a dustless, odorless combination of units, consisting of furnace, flash dryer, wet and dry sludge mixers, heat exchangers, and fly ash collector. Wet sludge cake is mixed with previously dried sludge from the hot gases in a cyclone, some being passed to the furnace where it is incinerated and some to the pug mill for mixing with wet sludge cake.

The multiple hearth incinerator consists of a refractory lined, steel jacketed circular unit containing four or more hearths, one above the other. Alternate hearths have openings at the center and alternate hearths have openings around the periphery. Rotating plows or rabble arms are attached to a hollow air-cooled vertical central motor-drive shaft and the teeth of the rabble arms break up the sludge and move it to the central or peripherial opening. In the Nichols Multiple hearth furnace drying takes place on the upper hearths.

In the "Martin Multizone" furnace (Morse-Boulger Co.) the top hearths are for drying, the middle hearths for incineration, and the bottom hearths for combustion. Vapors from the drying are drawn off and discharged into the combustion zone. In a modification of this furnace, wet sludge is added to the lower zone and is dried by downdraft from the incinerating zone, the dried sludge is then transferred by a conveying system to the top hearths.

This type of furnace has been used to burn thickened raw primary sedimentation sludge containing 85 to 90 per cent moisture. Although the heat value of raw sludge is higher (6000-7000 Btu. per lb.) compared to digested sludge (4000-5000 Btu. per lb.), this type of incineration requires more external heat (to evaporate the water) but it does eliminate the need for chemical sludge conditioning and vacuum filtration and the cost thereof.

In either type of furnace it is possible to obtain dried sludge or incinerated ash as desired. The ash is inert, finely divided, and can be used as fill. It has no residual nuisance characteristics whatever.

Lagoons

Lagoons, earth diked basins, have been successfully used as open digestion units (deep pit sludge digestion). Odors are relatively absent. Operation produces satisfactory sludge digestion and a clear supernatant liquor that can be discharged to streams. If the beds are used only for digestion, at least 0.17 cu ft is required per pound of solids added or roughly 0.017 cu ft per capita per day. If the lagoons are also used for dewatering as well as digestion, a capacity of 0.4 cu ft is required for each pound of solids added or 0.04 cu ft per capita per day, from which figure it is possible to calculate the approximate number of days required to fill a lagoon of known capacity.

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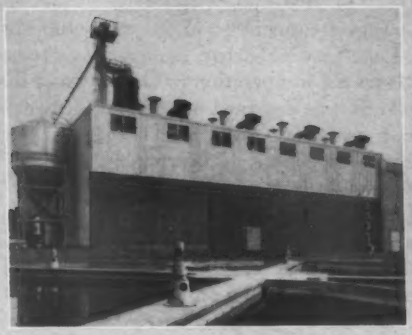
Rugged construction assures long life and low maintenance.

Pictured at right are a few of the recent Nichols Herreshoff installations.

Our engineers will be happy to provide more detailed information and assist in the solution of your sewage solids disposal problem—no obligation, of course.

Marietta, Ohio — **Consulting Engineers Alden E. Stilson & Assoc.**



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Asphalt Paved Sludge Beds

in Salt Lake City

by WILLIAM T. SOUTH

General Manager, Suburban Sanitary District, Salt Lake City, Utah

The sewage treatment plant for the Salt Lake City Suburban Sanitary District was put in operation in October, 1955. It was designed to serve a population of 40,000 people. There are twelve sludge beds, 125 feet long by 32 feet wide in two banks of six each. Originally the drying area was constructed with a coarse gravel base, then a layer of finer gravel with six inches of fine graded sand on the surface. A sub-drain extended the length of the beds between the drive strips at the base of the course gravel.

The operation and maintenance of this type of bed is relatively costly as it is almost impossible to use power equipment to remove the sludge without damaging the bed and cleaning and replacement of the filter sand is a perpetual problem. Plant operators inform us that the hand shoveling of sludge is one of the more undesirable tasks in their plant maintenance program.

Construction Details

Therefore, it was decided to experiment with one bed at our plant. In June of 1956 one bed was converted by removing the six inch layer of filter sand throughout the entire bed except between the drive strips. This was replaced with a four inch layer of compacted road base and a two inch surface of compacted ¼ in. minus asphalt plant mix. On this bed a slope

Table 1

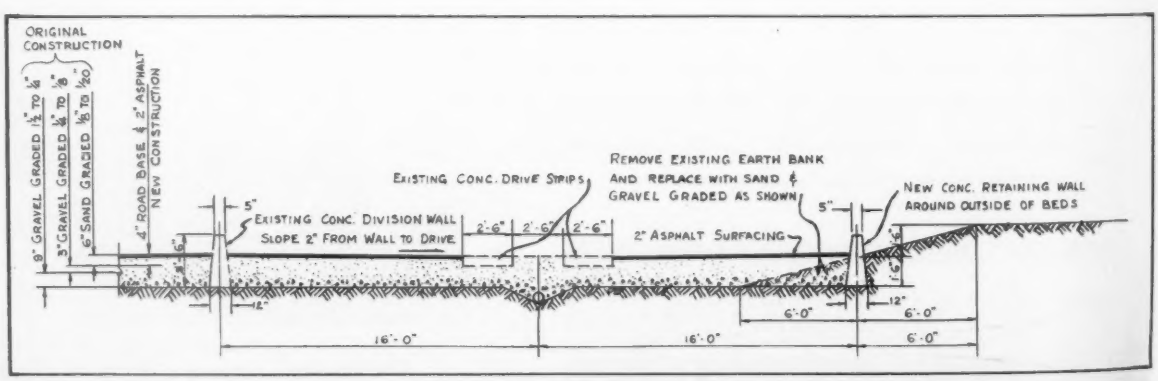
Drying Times

1956	Asphalt Bed	Sand Bed
August 3	Sludge drawn	Sludge drawn
August 13	No apparent difference on either bed	
August 18	Bed 85% dried	Bed 65% dried
August 22	Bed 100% dried and sludge removed	Bed 80% dried
September 1		Bed 100% dried and sludge removed

Table 2

Comparative Costs of Maintenance and Operation

Removal of sludge	Asphalt Bed		Sand Bed	
	hr.	Tot. Cost	hr.	Tot. Cost
Labor	--	----------	28	$56.00
Power loader	2	$12.00	----	----------
Truck	2	10.00	7	35.00
Replacing sand and cleaning:				
Labor	1	2.00	6	12.00
Filter Sand	¼ yd.	.50	3	6.00
Total Costs		$24.50		$109.00



CROSS SECTION through bed shows construction details that enable faster drying times, lower maintenance and operating costs to be realized.

of three inches from the side retaining walls to the drive strip was maintained for drainage purposes. This slope was reduced to two inches on the remaining beds. A retaining wall was constructed to replace any earth banks to facilitate loading with power equipment. The filter media and drains between the drive strips were left intact to provide drainage for surface water as well as to drain what might accumulate during the sludge drying process.

Tests and Costs

In order to determine the drying nature of this bed it was tested concurrently wtih a sand filter bed. The flow of sludge to the two beds was divided to assure a uniform quality in each bed. The results were then compared as shown in Tables 1 and 2.

Conclusion

It was concluded that with the drying time reduced and a net saving of $84.50 in maintenance costs each time a bed was drawn it would be advantageous to convert the eleven remaining beds. The plant superintendent, Mr. Emil Meyer, was strongly in favor of the change. Plans and specifications were drawn to include cement retaining walls to replace all earth embankments as well as the replacement of the sand with an asphalt surface. The low bid for the conversion was $11,776.00. The work was completed in October of 1957. It might be well to note that if a fine layer of sand is spread on the bed before it is first put into operation it will prevent bonding between the new asphalt and sludge, which could damage the surface of the bed.

South Salt Lake is now experimenting with one converted bed, and it is felt that after sufficient data is obtained, it will affect future designs of sludge beds in Utah.

Filter Cloths

by GEORGE F. FYNN
Superintendent, Sewage Treatment Works, Buffalo, N. Y.

Sludge disposal at the Bird Island Sewage Treatment Plant in Buffalo, N. Y., is handled by means of three vacuum sludge filters 11½ ft x 14 ft, with 500 sq ft of surface area.

Canton Flannel Cloths

At the inception of plant operation, utilization of canton flannel filter cloths was adopted for the filtering medium. Service of these cloths usually ranged from 180 to 210 hours with a maximum of 410 recorded. Chemicals originally employed for sludge conditioning preliminary to filtration comprised 40 per cent ferric chloride solution and milk of lime obtained from the slaking of pebble lime.

Reaction in the conditioning tub results in the formation of calcium carbonate and this latter material becomes imbedded in the interstices of filter cloth. Although this condition can be corrected by spraying the cloth with a muriatic acid solution, it has been uneconomical when the physical character of the cloth was such that the useful life was reached about the same time that a washing became necessary.

Some wool cloths and a blanket similar to that used on a Fourdrinier screen were procured for experimental purposes. Test runs, however, indicated that a change from the canton flannel was unwarranted.

Nylon Cloth

One manufacturer fabricated a 100% nylon cloth for the Buffalo installation. After the first 150 hours of service, this cloth was removed for inspection. The original cloth weight of 60 pounds was found to have increased to 254 pounds. The added weight was due to the imbedding of calcium carbonate in the pores. A complete acid wash restored the cloth to its original condition and it was again put in service. After an additional 309 hours of actual service during which time the cloth was acid washed five times, it was concluded that this particular fabric would not be economically satisfactory and further tests were discontinued. It is possible that more satisfactory service would have been obtained with more porous weave fabrication.

Dynel Cloth

Of more recent date, a dynel cloth was procured. The material was woven in a blanket for complete cov erage of the filter so that it was unnecessary to contend with weakening at seams. The unique property of the fibre has been its inertness to acids, weak alkalies, bacterial decomposition and mildew. Filtrate from the vacuum filter covered with this cloth contained about 200 ppm suspended solids when the cloth was clean. As the cloth became clogged with calcium carbonate, the filtrate showed a suspended solids content of 50 ppm or less. The decrease in suspended solids was used as a guide to schedule acid washing of the cloth.

A history of actual operation and maintenance requirements during the period the cloth was in service is portrayed in the following:

Dynel Filter Cloth

Total Hours of Service	Corrective Measures
558	Acid wash
732	Wire replaced
907	Intensive water wash
1042	Acid wash
1266	Acid wash and rewiring
1582	Acid wash
1830	Acid wash and rewiring
2091	Acid wash
2361	Acid wash
2559	Detergent wash and rewiring
2587	Wire loosened and rewound
2807	Acid wash
2953	Cloth removed

Review of the foregoing indicates that acid washing was required after usage of from 224 to 558 hours. Failure of the binding wire occurred after from 534 to 732 hours.

Normal operation is on a 5-day week schedule with a 48-hour shutdown period following continuous service for approximately 120 hours. The filter unit is washed thoroughly with plant water at the end of the operating week spraying with pressures at 60 to 90 pounds. The take-off blade for sludge cake is constructed of plastic material and under some conditions it has been necessary for the blade to be pressed rather tightly against the blanket with consequent abrasive action on the cloth.

Mechanical Difficulties Hinder Test

Discontinuance of usage of the original trial blanket was not occasioned entirely by the lack of further serviceability. A vexatious problem was encountered that required complete inspection of the filter units. It was discovered that copper piping and tubing within the filter drums had both corroded and eroded with subsequent formation of holes at joints and rounded portions. It appeared that the application of a vcuum created conditions whereby the circumferential surfaces of the filters were distorted permitting loosening of the wire It was necessary to replace a number of filtrate tubes in each unit.

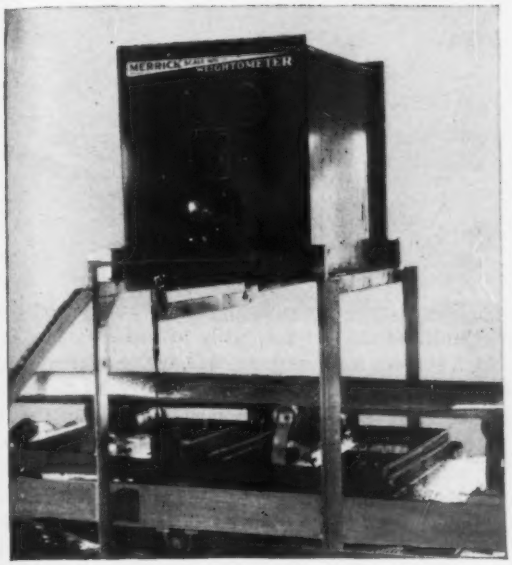
Davyhulme Plant Conversion

On the basis of performance given by the original dynel blanket, additional cloths were acquired. Inasmuch as necessary repair and maintenance of the filter units had not been fully completed, filter performance was erratic for a certain period of time. The next five cloths used furnished respectively 1791, 1892, 1629, 2293 and 1873 hours of service. Currently all three filters are covered with dynel cloths with several hundred hours of service on each unit.

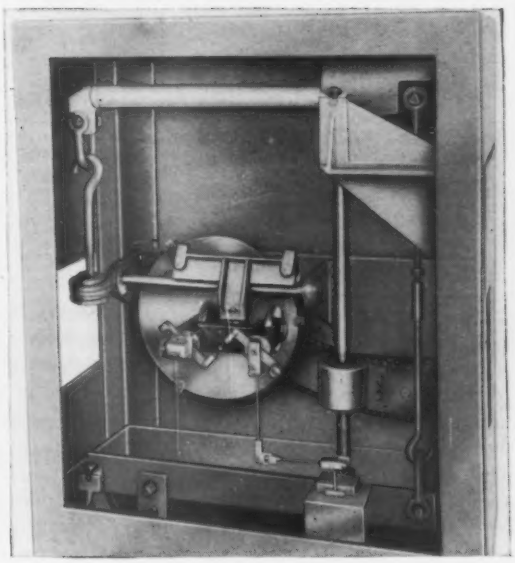
With an increase in unit cost of cloths of approximately 200 per cent, an increased useful life of over 800 per cent and concomitant economy due to less frequent windings and shutdown periods, the transition from canton flannel to dynel filter cloths has proved beneficial.

Make a continuous, accurate record of filter cake weight with a...

MERRICK WEIGHTOMETER®



Type E Weightometer.



Type SV Weightometer.

Accurate totals of the solids are easy when a sewage treatment plant has a Merrick Weightometer. The Weightometer continuously records the total weight of filter cake or sludge carried on a moving conveyor by measuring and integrating the varying load on the conveyor with the fluctuating speed of the belt. Proved by fifty years' use in every type of bulk materials handling found in industry, the basic principle of the Weightometer has been refined until accuracies of better than 0.5% can be guaranteed.

Any weight, any material, any capacity... There are no limits to the Weightometer's applicability. Any material, wet or dry, that can be carried on a conveyor can be weighed, accurately and continuously, with the total weight registered. There is no interference with the operation of the conveyor or the flow of material.

Compact, easy to install, operates by itself... The Weightometer can be readily installed on your existing conveyor without altering the conveyor's structure (see cut). It needs no extra floorspace. And since its operation is entirely automatic, no attendant is needed.

Negligible maintenance... All essential parts of the Weightometer are enclosed, effectively protecting them from dust and dirt and also preventing tampering by unauthorized personnel.

You can choose... electronic, mechanical, or electro-mechanical integrating and recording systems. Full information on each type is yours for the asking.

NEW, SIMPLIFIED, LOW-COST UNIT

The new Merrick one- or two-idler suspension system provides the answers for filter cake weighing and recording. It is a simplified, economically-priced unit, especially designed for sewage plant systems.

MERRICK *fifty years of "firsts" in automatic weighing*

MERRICK SCALE MANUFACTURING COMPANY
184 AUTUMN STREET, PASSAIC, N. J.

Metal Media Vacuum Filters

for sludge dewatering

by KELSIE B. SINGLETON
Supt. Sewage Treatment Plant Middletown, Ohio

Middletown sewage is different from that found in most cities because of its content of white water waste discharged from several paper mills in the city. The industrial waste from these mills may contain as much as 50,000 mg/L of solids and may have a volume of several million gal-however, the amount of domestic lons a day. In spite of this waste, sewage plus storm runoff and infiltration tends to keep the concentration of BOD at a reasonable level.

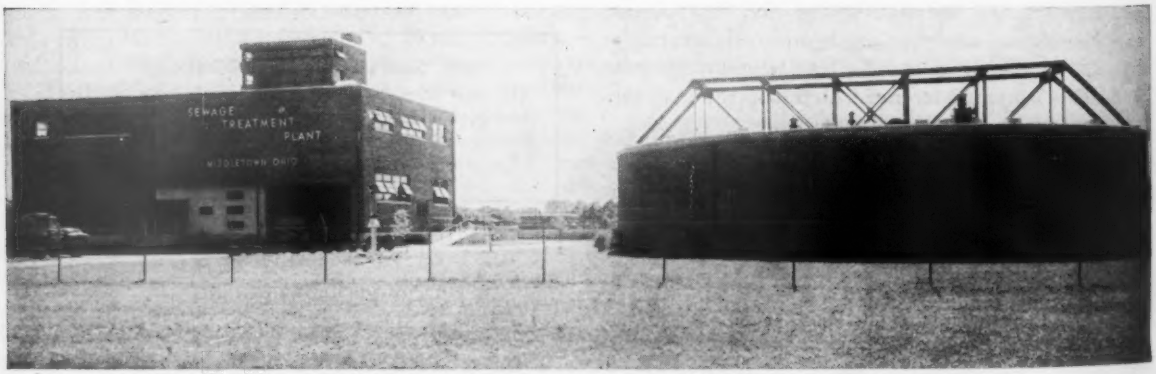
Although the population of Middletown is only 45,000 the total volume of sewage treated in the plant will run from 8 to 12 mgd; maximum flow is sometimes as high as 40 mgd during wet weather.

Sludge Problems

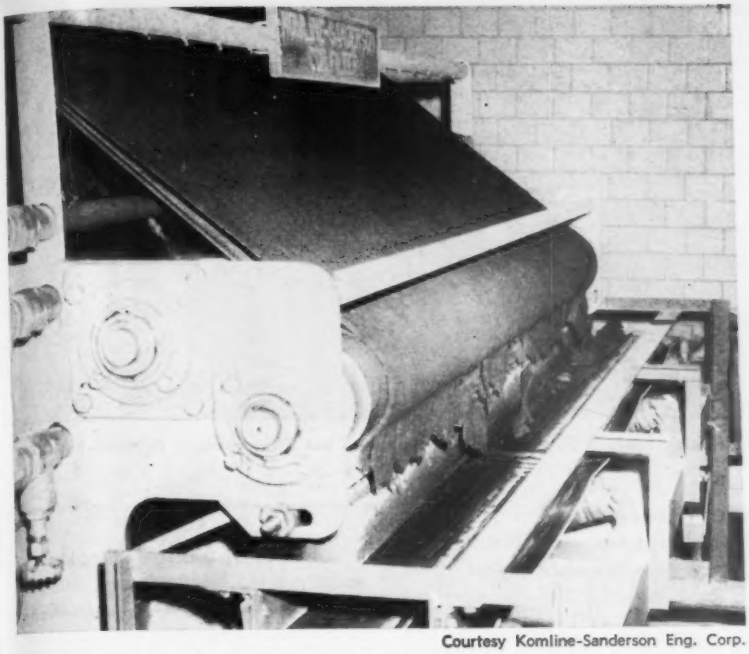
The industrial waste is mostly paper fibers plus small amounts of titanium oxide. A high percentage of the paper fiber is volatile. The Middletown plant is of the chemical treatment type and its operation is aided by the presence of the industrial wastes insofar as settling is concerned, but operation is hindered by the large amount of sludge that must be digested and dewatered. The total volume of sludge to be handled with a normal sewage flow of 8 mgd, may amount to as much as 100,000 gal per day. A brief analysis of this sludge is shown in Table 1.

Due to the nature of the paper mill waste, the sludge has a high compressibility and is therefore hard to dewater. It has been found that one method of improving the dewatering process is to start with the sludge in the secondary sludge digestion tank. Obviously, chemical conditioning of sludge is essentially an agglomeration process, or the collection of particles too small to filter into larger particles more easily to handle. Here at Middletown, this agglomeration process is started in the secondary digestion tank by pumping sludge from the bottom of the tank to the top of the tank. This procedure, which allows for slow settling of the sludge particles is continued at periodic intervals until, by calculation all of the sludge in the tank has been moved at least once.

This recirculation of sludge produces a rise in alkalinity, a decrease in volatile acids, a rise in pH and a decrease in the CO_2 content of the gas, all of which indicate a better condition in the digester. This procedure will admittedly produce a poorer supernantant liquor, but this condition only lasts as long as the recirculation is in process, and the advantages of improving the dewatering characteristics of the sludge far outweigh the disadvantages of poor supernatant liquor



MIDDLETOWN, Ohio sewage treatment plant handles mixed domestic sewage and paper mill wastes and utilizes . . .



Courtesy Komline-Sanderson Eng. Corp.

DEWATERED sludge is discharged from Coil Filter to rubber belt which moves sludge cake to disposal area.

returned to the raw sewage.

After the sludge has been recirculated and compacted as a result of this action, it is pumped to the filter room where equipment is provided for the addition of lime and ferric chloride. It is in the chemical conditioning process where the benefiits of recirculation of the sludge are reaped. It will be seen from the data in Table 2 that a number of chemical dosages were tried, using various combinations of lime and ferric chloride and lime alone. Experience showed that lime dosages of 12 to 13 per cent (pounds of lime per 100 pounds of dry sludge solids) gave just as good a cake as lower lime dosages with ferric chloride. The best results were obtained when the lime dosage produced a pH of 12.0.

Dewatering Costs

Having discovered how to reduce costs by eliminating the use of ferric chloride as a conditioning chemical, it was also found that costs could be reduced further by using reclaimed lime from the softening plant of the Dayton, Ohio water works. (The analysis is shown in Table 3.) By using this reclaimed lime at a dosage rate of 12 per cent, the cost of chemicals for conditioning is only $2.08 per ton of dry solids filtered. The cost of labor for sludge dewatering is $3.33 per ton of dry solids; therefore the total costs of dewatering sludge at Middletown is only $5.41, which appears to be well below the cost reported for other plants.

The data in Table 2 indicate that the moisture content of the sludge cake is low enough to insure that it can be handled readily. These data also show that the actual output of the filter in dry solids per hour is fairly uniform regardless of the amount of lime used, which indicates that higher dosages of lime did not increase the yield enough to make it worth the higher cost of treatment. Yields of approximately 5.0 lb per sq ft per hr of dry solids from the vacuum filter have been considered satisfactory, but anticipated yields of 7.0 lb per sq ft per hr were not obtained with this type of sludge.

Table 1
Analysis of Sludge

	Fresh Solids	Digested Sludge
% Solids	4.0	9.0—10.0
% Volatile	63.0	50.0
% Fixed	47.0	50.0

Reduction in vol. mat. 41.2%

A ready outlet for all filtered sludge has been found with a local sand and gravel operator, who supplies trucks and drivers at no cost to the sewage plant. By the use of certain pieces of gravel bank equipment, the sludge cake will be dried further and certain additives will be mixed in and the product sold as fertilizer. This arrangement removes, from the sewage treatment plant, the problem of ultimate disposal of the sludge and its attendant cost.

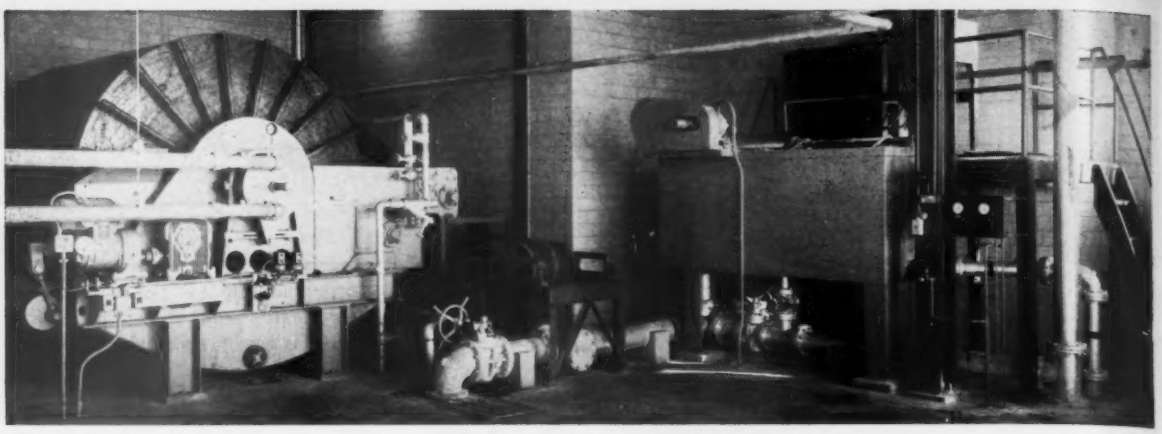
The filtrate from the vacuum filter is returned to the raw sewage wet well at the head of the plant and is pumped through all units along with the raw sewage influent. The data in Table 4 show that this filtrate does not affect the plant operation to any serious degree.

Operation Routines

Several things have been learned in regard to operating the vacuum filter unit and the dewatering process in general. For example, with this par-

Table 2
Experimental Data

Filter Run No.	Sludge Pumped Gal	Solids in Sludge %	CaO %	FeCl₃ %	Moisture in Cake %	Yield lb/sq ft/hr dry	Dry lb solids per hr
1	16,718	10.9	12.4	.....	67.32	5.6	1,407
2	8,229	10.2	14.9	.....	65.27	4.7	1,167
3	18,413	11.1	13.0	.....	68.92	5.4	1,340
4	25,301	10.0	12.5	.....	67.71	5.6	1,389
5	24,000	9.8	12.9	.....	68.0	5.4	1,353
6	23,183	9.6	7.4	2.04	68.08	4.7	1,178
7	23,625	9.22	7.6	1.66	69.78	5.0	1,253
8	19,681	9.00	14.8	.....	70.00	4.7	1,182
9	12,668	8.56	4.8	1.8	68.8	4.4	1,095
10	11,340	9.03	8.2	1.5	66.2	4.3	1,067
11	11,390	9.51	15.4	.....	67.3	4.5	1,129
12	25,000	9.54	15.0	2.4	69.0	5.3	1,326



FILTER ROOM contains vacuum filter and conditioning tank. The main building in which the filter room is situated has three floors below ground.

Table 3
Typical Analysis of Dayton Lime

Total Calcium Oxide (CaO)	91%
Magnesium Oxide (MgO)	5%
Silicon Dioxide (SiO_2)	2%
Iron Oxide (Fe_2O_3)	1.0%
Aluminum Oxide (Al_2O_3)	1.0%
Available Calcium Oxide (CaO)	90%

ticular type of sludge it has been found advantageous to subject the filter to a thorough washing after seven to eight hours of continuous operation. Washing requires about 45 minutes. Apparently the type of sludge obtained at Middletown is not washed off the coil spring filtering media to the fullest extent by the regular washing sprays with which the filter is equipped. Therefore it is necessary to subject the filter to a more thorough washing every shift in order to prevent the collection of foreign matter in the coils. If such a collection of foreign matter is allowed to accumulate, the effectiveness of the filter is decreased and sludge will pass through the filter. If this should happen, sludge entering the vacuum receiver might pass on through to the vacuum pump and blower. Fortunately, this simple operating procedure of regular washing obviates any possible difficulty from this problem which appears to be of a local nature.

It has been found that the depth of sludge in the pan, or in other words, the depth of submergence of the drum is important in optimum operating conditions. The higher the level of sludge in the vat, the less liklihood there is of pulling holes in the filter cake and the resultant loss of vacuum therefrom. It has been found that a 10-inch vacuum is sufficient. Just in case a hole should be pulled in the filter cake on the drum, the operator keeps a supply of cut-up papers on hand; if a hole appears, he simply applies a paper patch and loss of vacuum is prevented. Under normal operation, the use of such paper patches is not required and this "patching" is not a serious chore.

Among the problems of operation of the sludge dewatering plant are these two: The eight inch sludge lines from the conditioner to the filter have a tendency to plug with lime scale about once a week as do the lines from the lime slaker to the conditioning tank. Cleaning is accomplished by flushing. Because of this tendency to form scale, a centrifugal pump for transferring hot lime suspension from the slaker to the conditioning tank had to be replaced by a diaphragm pump which has proved quite satisfactory. This diaphgram pump is driven by a variable speed drive.

When operations permit a long shutdown period, the vacuum filter is thoroughly cleaned by using 15 gal of commercial HCl to remove any lime scale. The acid is added to the filter tub with enough dilution water to insure that the metal springs will be submerged when the drum is rotated. This cleaning procedure does a thorough job without injury to the stainless steel coil springs which make up the filter media. When such shut downs and cleaning occur, any loose springs are tightened to insure a proper filter media. After such a cleaning period, the filter is ready for another extensive run.

Table 4
Effect of Sludge Filtrate on Sewage

	Analysis of Raw Sewage	
	Without Filtrate	With Filtrate
Susp. Sol. Raw Sewage	242	308 ppm
B.O.D.—Raw Sewage	122	136
Total Solids— Raw Sewage	1014	1055
Total Solids—Effl.	771	781

The pumps for handling the sludge are of the plunger type and were furnished by the manufacturer of the filter equipment. These pumps are situated two floors away from the filter and are air controlled from the filter room. Cleaner pump operation is accomplished by furnishing running water to the plunger packing.

After a year of trial and error, sludge filtration at our plant has settled down into a routine, relatively easy operation. We feel that the filter operation is quite satisfactory. Any problems which have arisen because of the particular type of sludge we handle have been met and solved satisfactorily. In spite of the unusual sludge load at our plant we do not believe that the ordinary operating problems are any more numerous than they are at other plants.

One thing we can say: The plant operators responded readily to instructions from the manufacturer concerning the filter and now are excellent filter operators. Maintenance has been at a minimum, as have odors and mess. This has been our experience with a metal media type vacuum filter.

Sewage Sludge as Soil Conditioner

by The EDITORS

Organic Gardening and Farming Magazine, Emmaus, Penna.

Sales of sewage sludge to gardeners and farmers throughout the United States have increased in recent years. In cities such as Boise, Chicago, Wichita, Grand Rapids, Duluth, Omaha, Santa Fe, Schenectady, Houston, Roanoke and Milwaukee, superintendents of sewage treatment plants report that demand for sludge has been increasing.

F. C. Funnell, Jr., head of the Roanoke, Virginia sewage plant reports that his "customers use ground sludge at $2.00 per cubic yard on lawns. Unground sludge, at $1.50 per cubic yard, is used mostly in the gardens. Sales run about two-thirds of ground sludge to one-third of the unground. This is all in bulk sales since we do no bagging. Our experience with the material shows spectacular results on both lawns and gardens over and above the results expected from the nitrogen-phosphorus-potash analysis of the sludge."

Some of the larger cities market their sludge through fertilizer distributors. For example, H. J. Baker Brothers of New York sells both Houston and Chicago sludge. Others (most well known is Milwaukee) have set up their own marketing and advertising departments.

Spraying Groves

Florida Sanitary Engineer, Ralph Baker, Jr., describes how "several of our cities, namely Orlando, contract with local fruit growers for the use of liquid digested sludge which is pumped into tank trucks and then is sprayed upon the local citrus groves. Contract prices are usually in the range of $3.30 per thousand gallons."

The great majority of cities do not sell their sludge, but make it available to local gardeners and farmers free at the plant site. In Illinois, for example, according to Sanitary Engineer Carl Gross, "virtually every city and sanitary district which operates a sewage treatment works makes the digested and air-dried sludge available at the treatment works to anyone. In a few instances, there is a nominal charge but in general, the sludge is available at no cost."

Since 1948, Richmond, Indiana has been hauling liquid sludge for the benefit of neighboring farms. William Ross, superintendent of the plant, estimates that over 4 million gallons were hauled last year alone. A similar practice is carried on at Marion, Indiana, where usage has tripled since 1952.

For Beautiful Parks

"The City of Las Vegas has never placed on market the sludge from its sewage disposal plant. It has been the policy of the City to use the sludge for development of parks, recreational areas and cemetery facilities over the last few years," according to V. B. Uehling, Public Works Engineer. "The demand for sludge for these purposes by the Park Department has exceeded the actual supply. We've found that the sludge has been a very useful product in adding humus to the desert soils found in this area and in building the turfs within the park developments."

In Stratford, Connecticut, the sludge is shredded for park use and is also spread and mixed with sand for a fill over the refuse dump. "When mixed with sand, it makes a good binder holding the sand from blowing away and helps support the growth of rye used for a cover until the ground will support a good grass," explains the Stratford plant superintendent.

In Oshkosh, Wisconsin, sludge helped out the city's children. "We had a stock pile of sludge last year," R. Frazier, superintendent of the plant, told us, "and the park superintendent wanted to recondition his soft ball diamonds. In working out a plan, the sludge was ground and mixed with sand and clay and placed on the diamond. The results were surprisingly good. The diamond was more easily maintained, more life to the ground, dried out easier after the rains, etc."

The Right Approach

LeRoy Van Kleeck, Principal Sanitary Engineer of Connecticut's Department of Health, has done much research regarding the use of sludge as a soil conditioner and "has advocated the use of sludge for the above purpose for some years. His excellent report, "Digested Sewage Sludge as a Soil Conditioner and Fertilizer," contains illustrations of his property where sludge was used for a number of years with very gratifying results. Engineer Van Kleeck estimates that

at least 50 per cent of the sludge output from some 55 municipal sewage treatment plants in Connecticut is finding its way back to the soil.

"The use of sewage sludge we have found in Connecticut to be largely dependent upon a proper interest and approach on the part of the sewage plant superintendent. If he promotes its use and explains to people its limitations, it is favorably received by the public. In a few towns where no publicity is given to the material it is simply used as fill."

Schenectady Case History

Experiences at Schenectady, New York point up the validity of Mr. Van Kleeck's observation. "We have no special way of promoting our sludge soil conditioner, other than taking advantage of every opportunity to tell the public about its organic content and its ability to improve most every soil. It is my firm belief that we who are in charge of a sewage treatment plant are in duty bound to see that these organics are returned to the soil." Those are the words of Clifford E. Irving, superintendent of the Schenectady plant. Following is a history of his plant's experiences in marketing sludge:

"It was not until about 1924 when the first successful attempt was made to sell air dried sludge to the public. At that time, Morris M. Cohn then superintendent of the Schenectady plant, offered this material for sale at the astounding price of ten cents per load. This followed an unsuccessful attempt to give it away. By establishing a price for this product, the public was made to realize that it had some value. The farmers came with their trucks and loaded them until the springs were oxer-taxed. The customer wanted his money's worth and indeed he got it.

"Through the years, the price advanced to 25 cents per cubic yard. Some attempt was made to grind the sludge and offer it for sale at 25 cents per bag, the customer bringing his own container. With all of this promotion, a warning had to be issued with each sale, of the possibility of some pathogenic bacteria being carried over in the sludge. This naturally limited its use to those crops which went to the table cooked.

"By 1948 when plans and specifications were being drawn for the modernization of the Schenectady plant, we realized that we had a good market for organic soil conditioner and that we should do everything possible to take advantage of it. We, therefore, had designed into our specifications the now existing facilities, namely vacuum filters, flash drying, incineration, fly ash and odor control, and sludge bagging.

"The new plant was started in January of 1953, but it was not until January 1954 that there was sufficient sludge available to start processing. During this time we were actively engaged in a sales promotion campaign. We talked Orgro (the trade name which we adopted for our organic soil conditioner) to everyone with whom we had contact. We took advantage of all free newspaper, magazine, radio or television advertising we could get. We spoke to farm groups, garden clubs, parent-teacher groups, etc. We never allowed an opportunity to pass without plugging our product. We ran experiments to prove Orgro's value to our own employees for they are our best salesmen. Next we packaged Orgro in neat, easy-to-handle 65-pound three-ply paper bags.

"When we opened the door for sales in April of 1954, the entire inventory was completely sold in two days. We then limited customers to two bags per sale until September when we were able to meet the demand. Since that time our sales and production have increased each year.

"The following chart will present a cost picture of a typical day's operation at Schenectady.

	Dry	*Burn*
Labor	24.50	15.75
Fuel	31.38	13.44
Power	10.44	10.88
Bags	12.00	0.00
Tot. Costs	78.32	40.07
Revenue	100.00	0.00
	+21.68	—40.07

"It is obvious from this chart that there is over a $60 saving to the city every day we operate."

The Schenectady sludge has an NPK analysis of 2-2-½; annual output is 250 tons with less than 5 per cent moisture content, and is priced at $1.00 for a 65-pound bag.

Largest Commercial Set-up

Milwaukee and adjoining suburbs have an up-to-date sewage purification plant—the first one to use the activated sludge method on a large scale and to produce a high-grade fertilizer as a by-product. Its activated sewage treatment method removes 98 per cent of the bacteria and 95 per cent of the solids in sewage. The sludge product, Milorganite, is guaranteed to contain 6 per cent nitrogen and 3 per cent phosphoric acid plus many trace elements needed for plant growth. Almost a million tons have been produced and sold since production started in 1926. According to the Milwaukee Sewage Commission, the annual revenue from the sale of Milorganite exceeds $1,350,000 and covers about half the cost of operation.

Topsoil Building in New York City

For several years, New York City has been spreading sludge over some of its municipal park areas as part of a "topsoil building" project. Mr. Edward Brady, Director of Special Projects of the New York City Park Department, developed an entirely new method of applying the sludge. Here's how it is done:

Tankers carrying the sludge deliver it at a pumping station on the bay (Jamaica Bay), where it is pumped through two 12-inch cast iron pipes to the park site. After the land is graded with earth-moving machines, a network of six-inch aluminum piping, purchased from an irrigation equipment company, is laid over the area to be treated.

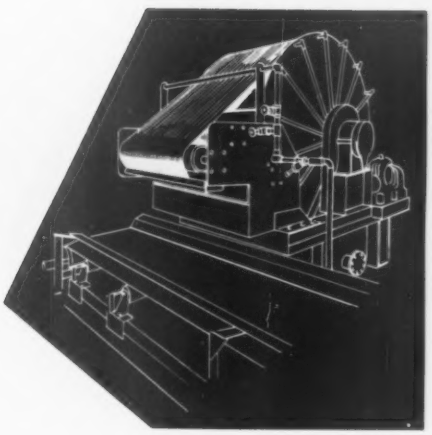
At regular intervals along this piping, portable fire engine deckpipe nozzles mounted on dollies are set into the pipes. Thus the liquid sludge, relayed by gasoline centrifugal pumps, can be evenly distributed over large areas at a time, each nozzle sweeping back and forth under the control of a single man.

About a gallon of the sludge per square foot is applied at each spraying. It is allowed to dry about three days, depending on the weather, then disked in. Every section of ground is sprayed and disked 16 times, until approximately four inches of sludge has been applied. The diskings mix this in seven to nine inches. The results has been a rich, dark topsoil perfect for park lawns, golf course and other recreational facilities.

Cost-wise, Mr. Brady analyzes it

THE COILFILTER STORY

SECOND DECADE



KOMLINE-SANDERSON ENGINEERING CORPORATION

COILFILTER

PROVED SLUDGE DEWATERING WITH PERMANENT FILTER MEDIA

In the few years since the first working installation, at Liberty, New York, in 1949, the Komline-Sanderson Coilfilter has become the first choice of engineers and municipal officials for the efficient and economical dewatering of raw or digested sewage sludge. This pre-eminent position in the vacuum filter field was earned—and is maintained—on the basis of day-by-day performance.

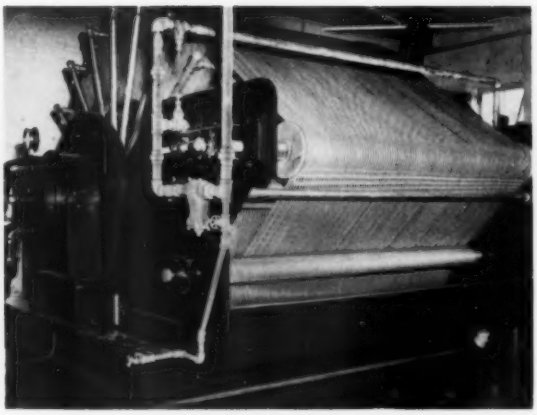
WHAT IS THE COILFILTER?

The Coilfilter is the creation of the imagination and inventiveness of T. R. Komline who, with W. H. Sanderson, formed Komline-Sanderson in 1946 and set up shop in a small plant in Glen Rock, New Jersey. In 1950 the move was made to the present site in Peapack, New Jersey.

The Coilfilter was designed to answer the need for an efficient filter unit:

a. Without the old-fashioned cloth filter media that required a complete shutdown for cleaning or replacement at frequent intervals.

- **NON CLOGGING**
- **CONSTANT OUTPUT**
- **PERMANENT FILTER MEDIA**
- **ECONOMICAL OPERATION**



Liberty, N. Y.

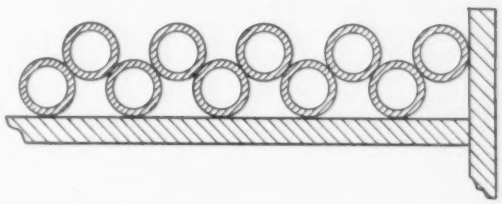
b. Constructed entirely of wear and rot-resistant materials.
c. Requiring a minimum of labor and maintenance.
d. Providing a constant, uniform product.
e. Universally applicable to all types of sludge.
f. Making sludge beds unnecessary.
g. Permitting a more compact, more economical plant.

The Coilfilter fulfills all these requirements, and many more. It is the modern sludge vacuum filter designed for the modern, growing community, where adaptability, dependability and economy are fundamental requisites.

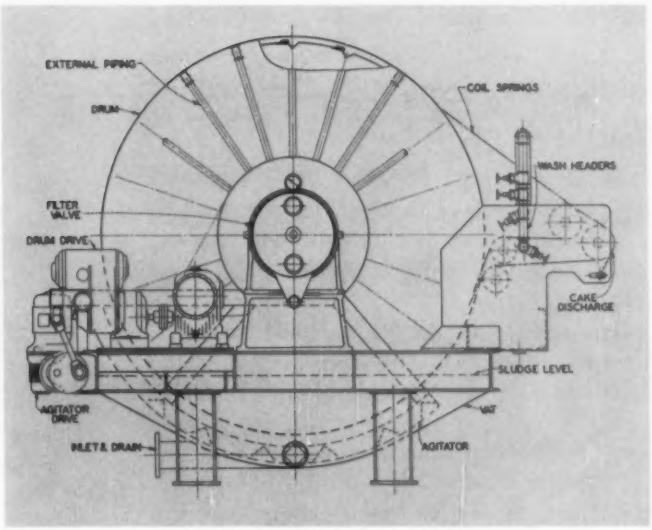
THE COILFILTER PRINCIPLE...

The basic Coilfilter principle is incorporated in its effective and exclusive permanent-type filter media and the performance derived from its continuous flexing and automatic cleaning action. This filter media consists of two layers of stainless steel, helically coiled springs 0.410" in diameter, placed in corduroy fashion around the filter drum. (See line drawing at right)

During the cake formation and cake drying cycles, these springs are wrapped around the slowly revolving drum, the lower layer being in grooves in the division strips of the drum so that the springs are taken off a portion of the drum and separated from each other by two discharge rolls in such a manner that the cake is lifted off the lower layer and is discharged from the upper layer of springs by means of a tine bar. Both layers are then washed by means of special flat spray nozzles and reapplied to the drum by grooved aligning coils.



As the coil springs travel over the discharge rolls they bend, or flex, first in one and then in a second direction, while being washed. This guarantees a constantly clean filter media as it begins the dewatering cycle, one of the reasons for the Coilfilter's remarkable success.



Coilfilter Elevation

COILFILTER ECONOMY

The self-cleaning, permanent-type filter media of the Coilfilter (described in detail on page 3) produces a greater volume of filter cake, with greater uniformity, than any other type of sludge dewatering equipment. This makes possible a smaller plant, at less cost.

Since the permanent type filter media does not clog or blind, chemical conditioning of the sludge is far less critical than with other types of filters. Lower-than-optimum chemical dosages are very often permissible, resulting in considerable savings.

The Coilfilter requires no stand-by filter unit, since the equipment does not require shut-down for cover changing or replacement. Nor is the full time of an operator required while the unit is filtering. Coilfilter's low maintenance needs, external piping design, with rugged, stainless steel drum deck and springs, completes a picture of true economy.

FRESH SOLIDS DEWATERING

Dozens of municipalities are now enoying the advantages of raw sludge (fresh solids) dewatering on Coilfilters, the only filter equipment that can perform this operation successfully and continuously on a trouble-free basis. These advantages are important to every community considering a new plant or the expansion of present overloaded facilities. In brief they are:

LOW INSTALLATION COST

A Coilfilter-equipped fresh solids dewatering plant costs less to install than a system that includes digesters and sand beds. Fewer structures and less land area are required. The capital investment needed is well within the reach of small and medium-sized communities.

ECONOMY OF OPERATION

Operating and fixed costs for a fresh solids dewatering installation are lower than for digestion and drying. Operational problems and costs are minimized by the elimination of this added equipment.

FREEDOM FROM NUISANCE

With standard chemical conditioning, dewatered fresh sludge does not produce odor or other nuisance, and bacteriologically is suitable for standard methods of disposal.

FLEXIBILITY

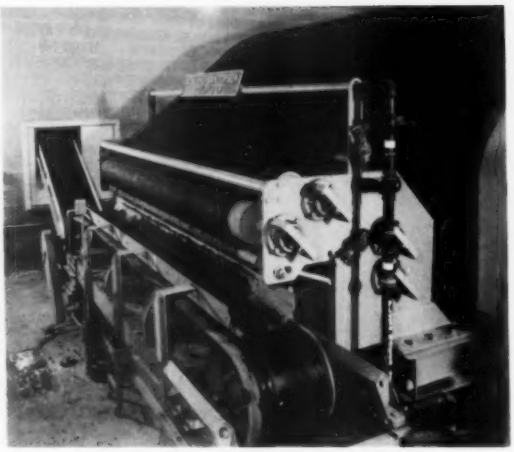
When industry is involved, use of the Fresh Solids Process permits direct and economical handling of wastes that, if digesters were employed, would require expensive pre-treatment by the industry. This feature is particularly attractive to municipalities desirous of seeking new industry.

WHY COILFILTER LEADS THE FIELD...

As the only *performance-proved* sludge vacuum filter with permanent-type filter media and as the leading modern sludge filter, by far, in the municipal sewage treatment field, the Coilfilter offers design, construction and operating advantages available in no other filter system. Some of these advantages are:

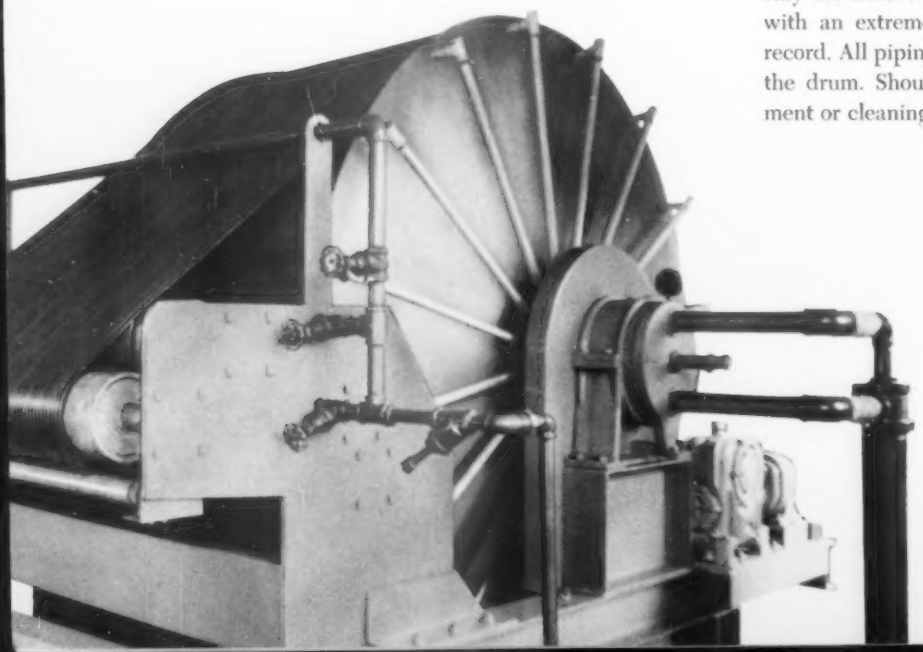
PERMANENT, NON-CLOGGING FILTER MEDIA

Stainless-steel, helically coiled spring filter media cannot clog or blind and has an indefinite life. Automatically washed after each dewatering cycle, the filter media results in greater production of cake, with no time lost in media cleaning or replacement.



RUGGED CONSTRUCTION

Since the Coilfilter is manufactured entirely of wear and rot resistant materials, it is immune to ordinary deterioration and will last indefinitely. Komline-Sanderson uses only the finest materials. Result—a product with an extremely low parts replacement record. All piping is straight and external to the drum. Should it ever require replacement or cleaning, the job is quick and easy.



...PERFORMANCE-PROVED FEATURES

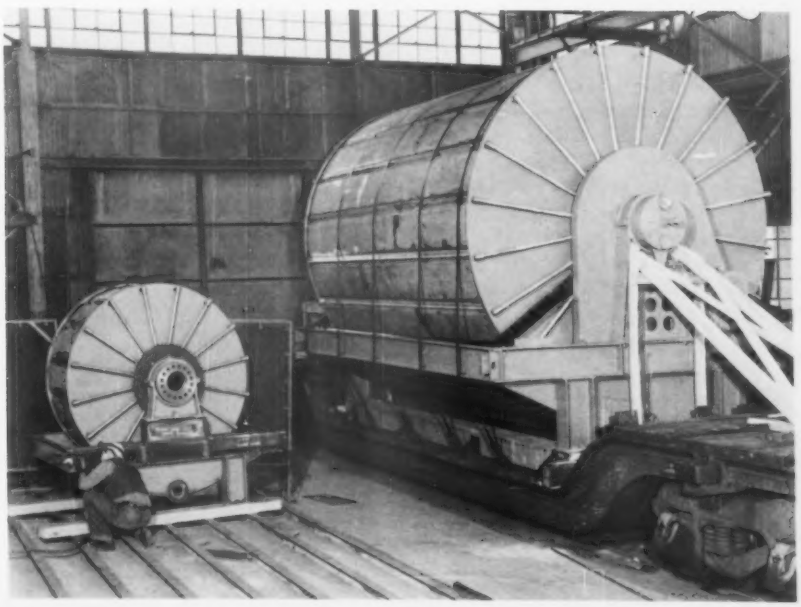
CONSTANT OUTPUT

No sludge dewatering system can match Coilfilter's performance-proved volume of filter cake production. Non-clogging, self-cleaning filter media maintain constant, uniform efficiency, making costly controls unnecessary.

OPERATING AND CAPITAL COST ECONOMY

The Coilfilter is the most economical of all sludge vacuum filters:

1. Fresh solids dewatering process, where used, reduces costs, both capital and operating.
2. No standby filter necessary, reducing size of installations and number of units required.
3. Lower chemical conditioning requirements—less cost.
4. Sludge drying beds unnecessary. More compact plant.
5. Little operating labor required. No filter cloths to change.
6. Extremely low maintenance requirements. Easy cleaning. Very little parts replacement.



The big and little of it. A 575 sq. ft. unit and a 50 sq. ft Coilfilter being readied for shipment.

KOMLINE-SANDERSON SERVICE

Komline-Sanderson service begins at the very start of a project. After our representative has discussed the design conditions and requirements of a future plant with the Consulting Engineer, and transmits this information to the home office, our experienced staff goes over the conditions and makes its recommendations.

The Engineer then receives a complete discussion of the bases used in arriving at our recommendations, together with sample specifications, typical layouts which may be appropriate, detailed equipment drawings and a price and weight analysis. Our Engineering Department is always available for whatever help and guidance we can offer.

After an order is received for Coilfilter and auxiliary equipment, we furnish promptly detailed layout and equipment drawings as well as certified specification sheets.

Komline-Sanderson always furnishes the services of a competent and experienced service man for a period of two weeks to supervise the initial operation and to provide proper instruction to the operators in the operation of the complete filter installation. Our service men also check on proper installation. After beginning operation the Service Department is always available for advice or personal call when needed.

INSTALLATION

We have developed and are continuing to develop and improve much of the auxiliary equipment used in Coilfilter installations. In order to assume complete responsibility for the proper performance of the complete sludge dewatering installation, it is our policy to furnish all necessary equipment: **1.** Coilfilter **2.** Vacuum and Filtrate Equipment **3.** Conditioning Tank **4.** Wet Sludge Handling Equipment **5.** Conditioning Chemical Feeders, Pumps and Tanks **6.** Cake Handling Equipment.

Our Engineering staff is ready to submit preliminary performance data involving the use of Coilfilters in your plant, upon receipt of the following information: **1.** Type of treatment plant. **2.** Whether sludge is to be digested. **3.** Design data, flow and suspended solids or population equivalent. **4.** Number of hours of filter operation per week desired.

USERS APPROVE COILFILTER

Here is what a few users have to say about Coilfilters:

LIBERTY, NEW YORK

HARRY EICHENAUER, Plant Superintendent: *". . . In regard to coil spring filter as compared to cloth filter, I would much prefer the coil spring. I used a cloth filter here for about ten years before replacing it with the coil spring. . . . If your chemical dosage should be a little off one doesn't have to worry about blinding, as with a cloth filter. After having operated the two kinds, I much prefer the coil spring. . ."*

ST. CHARLES, ILLINOIS

WM. B. CLARKE, Superintendent of Public Works: *". . . And, with the Coilfilter, chemicals now required for sludge conditioning are less than 50% of the quantities formerly used; the chemical treatment is no longer critical; the coil spring filter media never clogs or blinds; manual cleaning and replacement of the filter media has been eliminated; and operating headaches have disappeared. . . ."*

CONSHOHOCKEN, PENNSYLVANIA

CLARENCE H. COOPER, Superintendent: *". . . This unit replaces two old style cloth type filters whose operation and maintenance costs were entirely unsatisfactory. We feel the Coilfilter embraces truly sound design and exceptional performance, a combination that reflects in a savings of chemical usage and maintenance costs."*

BUCKLIN PT., RHODE ISLAND

C. V. (BUCK) HICKEY, Plant Superintendent: *"We have been very pleased with our Coilfilters from the beginning, due to their outstanding performance, dependability and low operating cost. In addition, the ease of maintenance, partly due to the accessibility of all points requiring lubrication and adjustment, combined with the excellent general layout of this plant, make this a truly modern installation."*

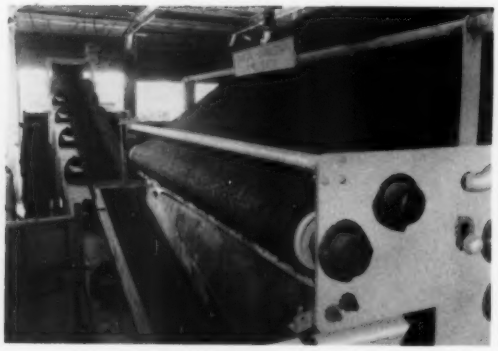
COILFILTER STANDARD SIZES

SIZE	AREA SQ. FT.	SIZE	AREA SQ. FT.
*7′ dia. x 2′10″ face	60	10′ dia. x 8′ face	250
*7′ dia. x 4′ face	85	10′ dia. x 10′ face	300
*8′ dia. x 4′ face	100	10′ dia. x 12′ face	350
8′ dia. x 5′ face	125	11′6″ dia. x 10′ face	350
8′ dia. x 6′ face	150	11′6″ dia. x 12′ face	430
8′ dia. x 8′ face	200	11′6″ dia. x 14′ face	500
10′ dia. x 6′4″ face	200	11′6″ dia. x 16′ face	575

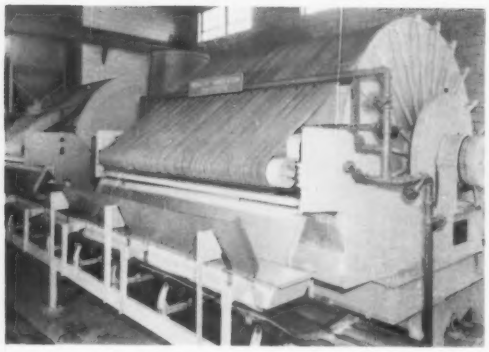
*Package Unit

SOME COILFILTER INSTALLATIONS . . . .

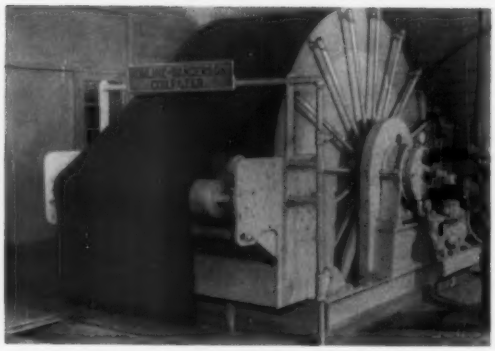
Warren, Mich.



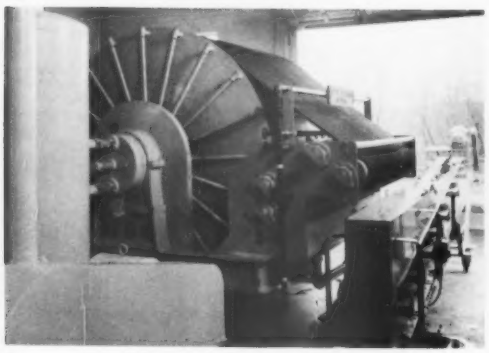
Norristown, Penna.



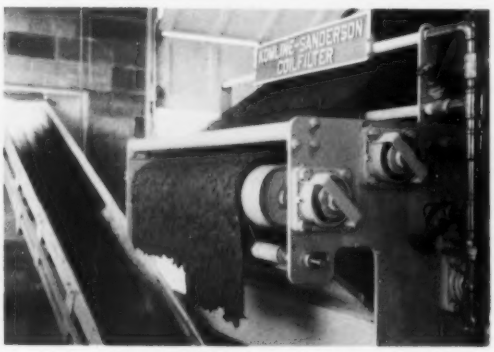
Woodbridge, N. J.



Merrill, Wis.



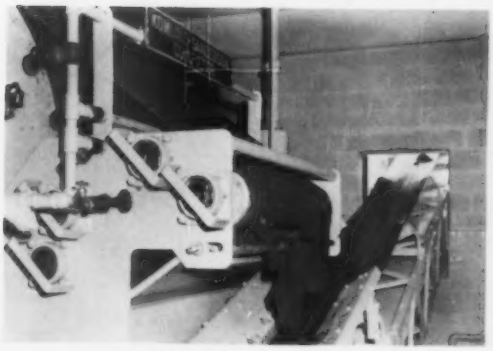
Carlisle, Penna.



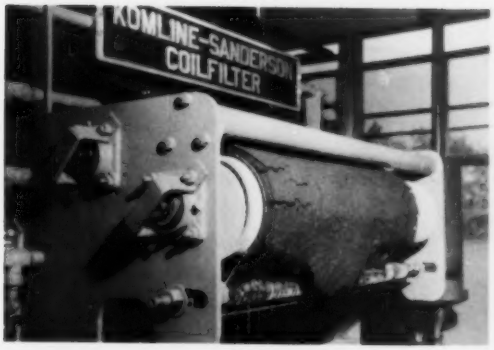
Cozad, Neb.

. . . . . IN THE MUNICIPAL FIELD

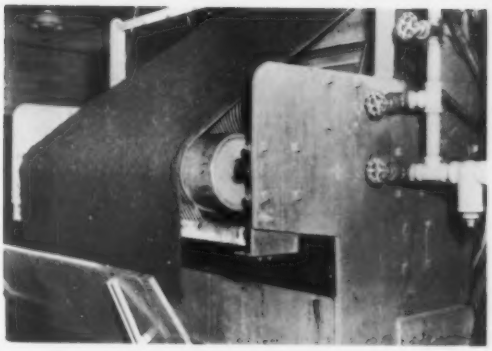
Dubuque, Iowa



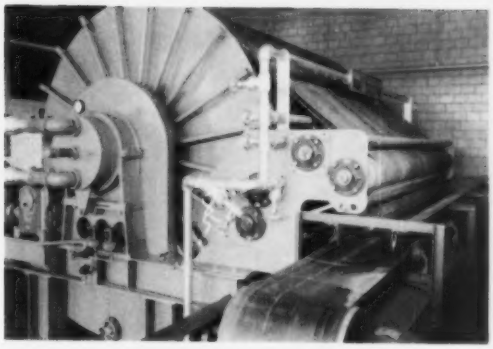
Elizabethton, Tenn.



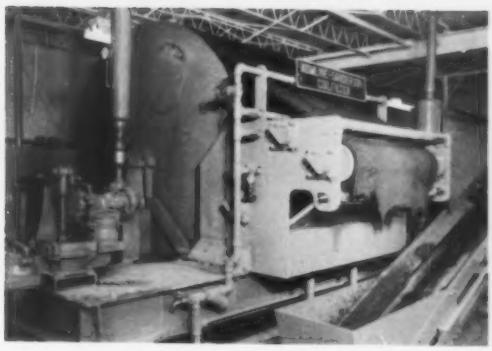
Cayuga Heights, N. Y.



St. Charles, Ill.

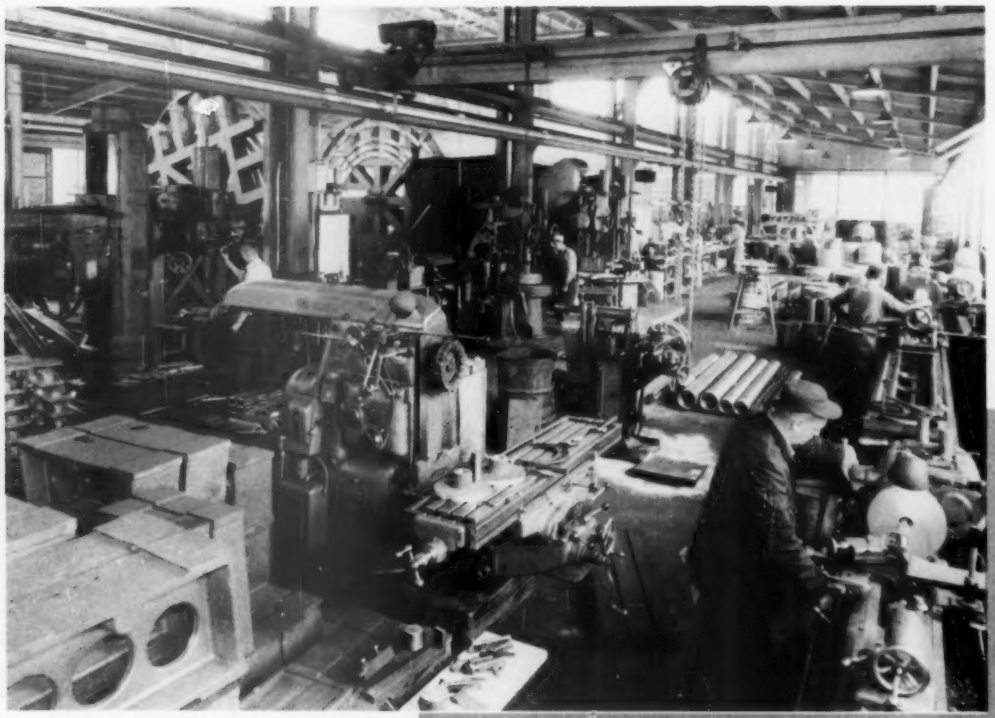


Middletown, Ohio



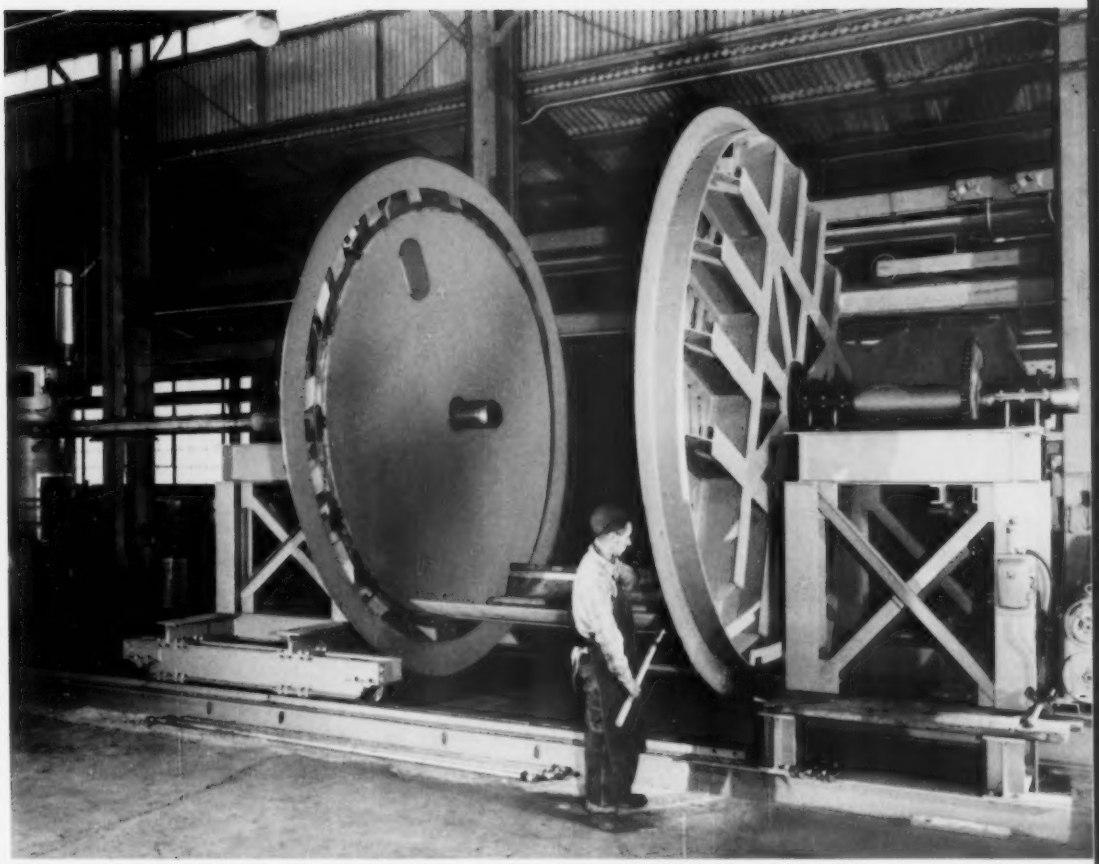
Trenton, Mo.

COMPLETE FACILITIES

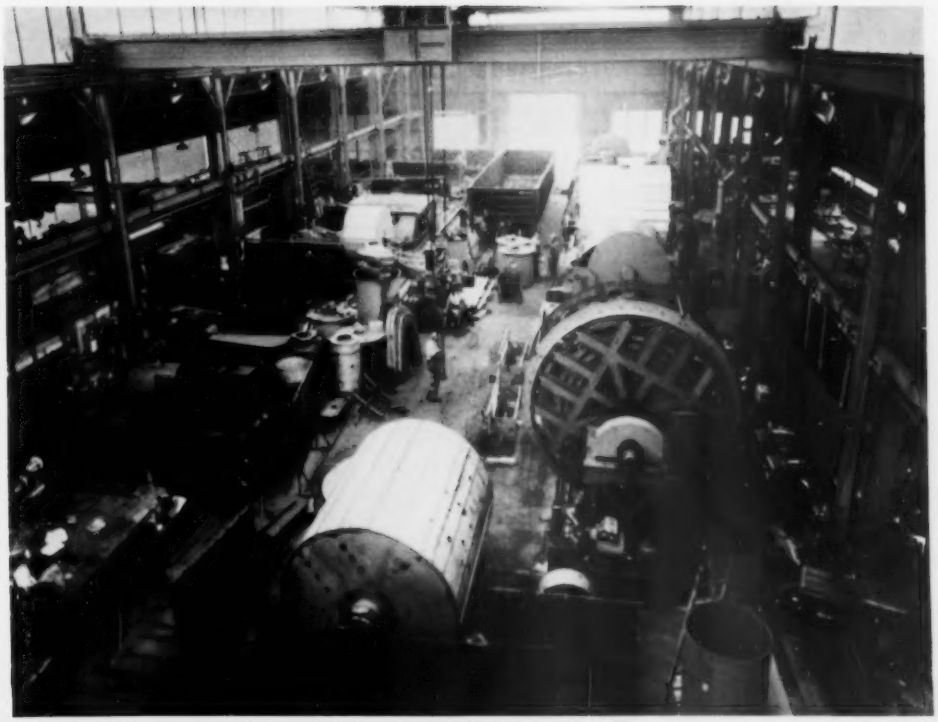


Above: a section of our large and completely equipped machine shop.

At right: Part of the Komline-Sanderson Engineering Department.



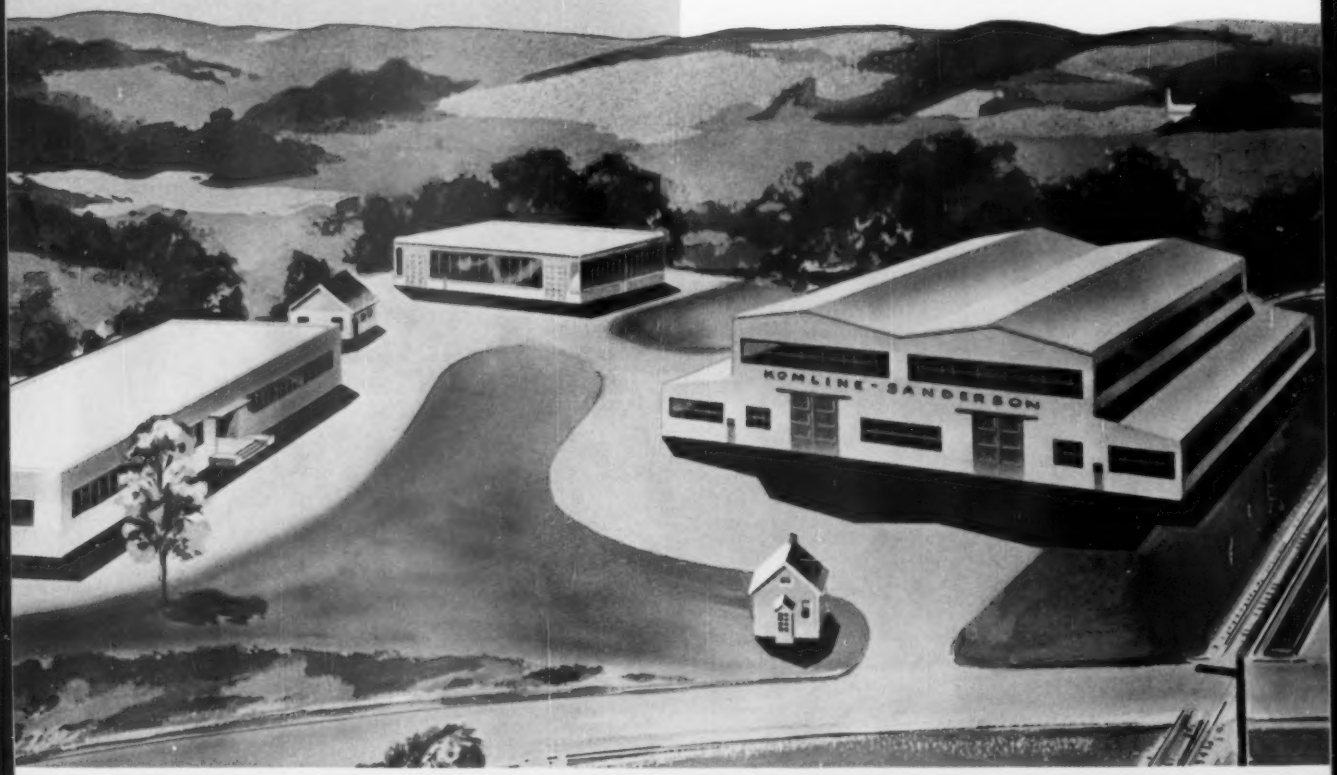
Above: Large, adjustable welding jig in our machine shop, used in fabricating COILFILTER drums.

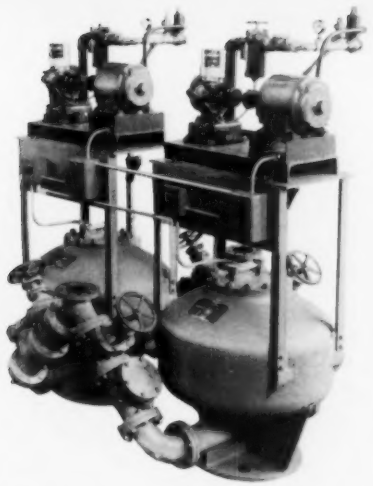


View of assembly section of manufacturing plant.

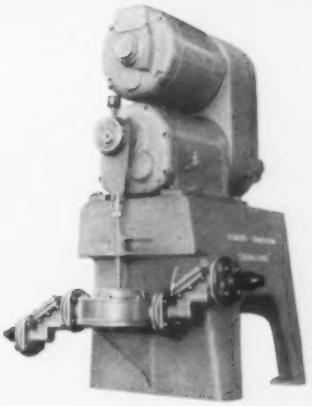
Above: Research and development activities are centered in this modern, well-equipped laboratory.

Birds-eye view of Komline-Sanderson Plant.

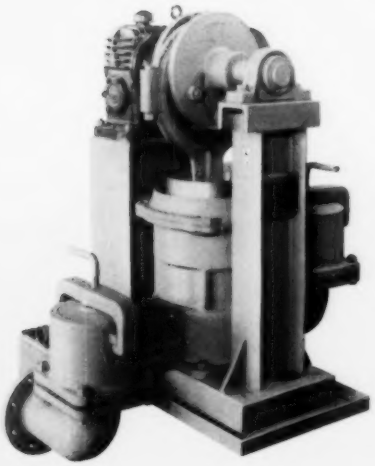




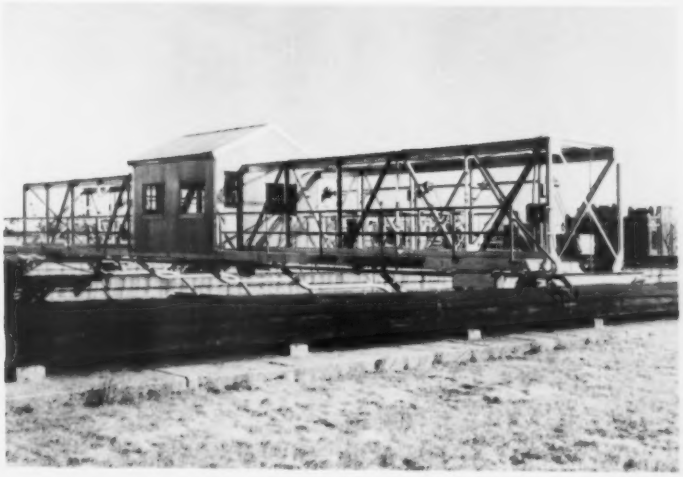
Pneumatic Ejectors



Chemical Feeder Pumps

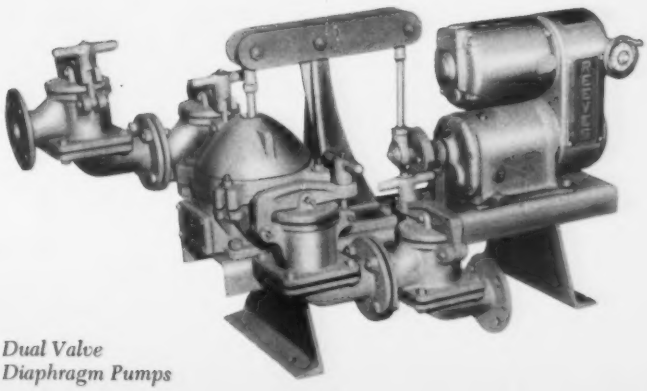


Heavy Duty Plunger Pumps

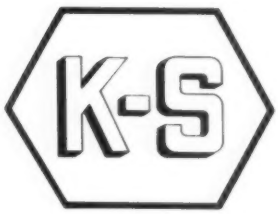


Rectangu-line Sludge Collectors

OTHER KOMLINE-SANDERSON PRODUCTS FOR THE SANITARY ENGINEERING FIELD



Dual Valve Diaphragm Pumps



DEDICATED TO THE CONSERVATION OF AMERICA'S RESOURCES

KOMLINE-SANDERSON ENGINEERING CORPORATION
PEAPACK, NEW JERSEY

Bulletin No. 108 5/59

Printed in U.S.A.

Table 1

Prices of Sewage Sludge

City	Brand Name if any	Annual Output	Nitrogen	Phosphorus	Years Sold	Sales Trend	Price
Birmingham, Al	.....	48,000 cu yds	2.25	3.0	24	No change	$1.50 per cu yd rough grade, $3.50 per cu yd ground
Phoenix, Ariz.	Air Dried, Digested	About 5000 tons	(no recent analysis)		25	No change	$3.12 per ton air dried
San Diego, Calif.	Nitro Gano	3,500 tons	2.75	4.54	1943-1955	Down	$6.00 per ton contract price, —$2.80 per 100 lb, bagged
Bristol, Conn.	Sludge Soil Conditioner	600 cu yds	2.69	2.52	5	Up	$.25 per bushel, pulverized; $1.60 per yd, sludge cake
Boise, Idaho	B.I. Organic	200-350 tons	3.59	.....	5	Up	$3.15 per 80 lbs, retail bagged
Chicago, Ill.	Dried activated sludge	125,618 tons	.....	.....	17	No change	All sludge shipped in bulk—no bagging
Fort Wayne, Ind.	.....	3,000 tons	2.5	2.5	18	Upward	.....
Indianapolis, Ind.	Indus	50 tons per day	5	2.7	Less than a year	.....	$22 per ton
Richmond, Ind.	.....	4.06 mil gal of Liquid Sl.	(No analysis made)		9	Up	.....
Mishawaka, Ind.	.....	152 tons	2.66	1.12	4	Up	.....
Jasper, Ind.	.....	50 tons	5.89	3.49	8	Up	.....
Marion, Ind.	.....	921 tons	1.49	1.45	16	Up	.....
Wichita, Kan.	Wichita Soil Conditioner	5,000 cu yds	2.1	.2	8	Up	$2.00 per cu yd loaded at plant, $3.00 per cu yd delivered in city, $4.00 per cu yd delivered 10 mi beyond
Battle Creek, Mich.	Battle Creek Plant Food	200 tons	2.8	2.6	13	No change	$2.00 per 100 lb, bagged
Grand Rapids, Mich.	Rapidgro	600 tons	2	2	25	Up	$1.00 per 80 lb, bagged
Duluth, Minn.	Soil Conditioner Sewage sludge fertilizer	44 tons	1.0	1.5	15	Up	$1.00 per 100 lb, bagged

this way: "It costs the Department of Public Works approximately $560 a tanker load (250,000 gallons) to transport and dump sludge at sea. Three loads a week used to be carried away from the treatment plant that now supplies the topsoil project. So the city is saving over $1,600 a week —and at the same time producing the most vital substance on earth from a material formerly a complete loss."

Activated or Digested?

The fertilizer value of the sludge produced depends largely on which processing method is used.

1. Activated sludge: This kind is produced when the sewage is agitated by air rapidly bubbling through it. Certain types of very active bacteria coagulate the organic matter, which settles out, leaving a clear liquid that can be discharged into streams and rivers with a minimum amount of pollution.

Generally, activated sludge is heat-treated before being made available to gardeners and farmers; its nitrogen content is between 5 and 6 per cent, phosphorus from 3 to 6 per cent. Its plant food value is similar to cottonseed meal—a highly recommended organic fertilizer.

2. Digested sludge: This type of residue is formed when the sewage is allowed to settle by gravity, collected, and pumped to a digester. The conventional anaerobic digestion system takes about 10 to 14 days from the time the sewage reaches the tank until the digested solids are pumped into filter beds of sand and gravel for drying. The final step is removal of the dry material, either to be incinerated or used for soil improvement.

A few medium-sized cities located in agricultural areas dispose of a part of their digested sludge in liquid form. This is delivered to farmers within a radius of about 10 miles and is used for direct application to land.

Digested sludge has about the same fertilizer value as barnyard manure. Nitrogen varies from two to three per

Table 1 (Continued)
Prices of Sewage Sludge

City	Brand Name if any	Annual Output	Nitrogen	Phosphorus	Years Sold	Sales Trend	Price
Grand Island, Nebr.	.....	about 1 ½ ton per day	4.2	.....	....	.....	.....
Omaha, Nebr.	.....	500-600 tons	2.5	1.5	16	Up	$1.00 per 100 lb, bagged $1.10. $15.00 ton delivered in bulk, grounded form
Flemington, N. J.	.....	80 tons	....	.....	77	No change	.....
New Brunswick, N. J.	.....	2,100 tons	1.77	2.18	20	Downward	.....
Pennsauken, N. J.	.....	200 tons	....	.....	33	Upward	.....
Santa Fe, N. Mex.	.....	500 tons	....	.....	4	Upward	$2.50 per 100 lb, bagged ground
Schenectady, N. Y.	Orgro	250 tons	2	2	4	Upward	$1.00 per 65 lb, bagged
Fargo, N. D.	.....	12,000 tons	....	.....	20	No change	$.50 per 1000 lb,
Oklahoma City, Okla.	Soil Booster Organic Fert.	.....	6 (fortified)	2	8	Upward	$3.60 per 100 lb,
Houston, Texas	Hou-Actinite	12,000 to 14,000 tons	5	3	7	Upward	Sold only in bulk $3.00 per unit of nitrogen, $.50 per unit of phosphorus
Roanoke, Va.	.....	1,688 tons	2.5	1.5	4	Upward	$.25 per 100 lb.
Fond du Lac, Wisc.	Fond du Green	2,000 tons	2	2	7	Upward	$2.00 per 80 lb, bag, $18.75 per ton
Milwaukee, Wisc.	Milorganite	70,000 tons	5.5	4	30	Upward	
Oshkosh, Wisc.	Oshkonite	600 tons	2.09	2.65	20	No change	Sold in bulk 2 bu.—$.25, cu yd—$2.00, Ground $3.00 cu yd No deliveries.
Sheboygan, Wisc.	.....	1,000 tons	1.96	1.65	11	Upward	$.50 per 80 lb bagged (retail local). Carload shipments price $5.75 per ton. (Sold to broker.)
Williamstown, Michigan (Compost undigested sludge and garbage)	.....	.....	2.1	2.1	1 ½ yrs. (in operation)		$40.00 per ton, F.O.B. the plant, Processor blends with peat moss, sells 3 qt polyethylene bags.

cent, phosphorus averaging about two per cent. It often has an offensive odor that persists for some time after application to a soil surface during cool weather. "This odor differs greatly in character, however, from that of raw sludge," Dr. Myron Anderson, senior chemist for the Agricultural Research Service at Beltsville, Maryland, states "since drastic changes have taken place during digestion. The odor from digested sludges may be eliminated by storage in a heap during warm weather."

This reminds me of the experience one editor of a trade publication in the public works field recently told me about. He had moved into a new home on Long Island and had the most common problem of how to build a good, permanent lawn. Because he knew about the value of sludge—especially on sandy soils, he contacted the superintendent of a local disposal plant and arranged to have him deliver several truck loads of sludge. The result—the most luxuriant lawn in his neighborhood. Side result—a next-door neighbor offended about the odor.

Several months later, this same neighbor wanted to know who to contact so he could have some sludge spread on his lawn. That's how the story ended—green lawn winning out over temporary smell.

Sludge Sales Snags

Marketing sludge on a successful commercial basis is not a simple task, as most plant superintendents realize. Enthusiasm on the part of plant operators and city administrators is not always enough to spark a demand for sludge among local gardeners and farmers. For example, in Maryville, Missouri, City Engineer Roger Higgins writes that "We do not sell any sludge—in fact we have a difficult time giving it away."

In Akron, Ohio, "there was a time a number of years ago when it was sold as Akra-Soilite but since the administration did not see fit to actually set the drying and selling of the

Table 2

State Reports—General Practice of Sludge Disposal

	State	Market	Token Fee	Free	City Use	Not Used as Soil Conditioner
1	Ala.	X-L	X	X	X-E	
2	Ariz.		X-L			X
3	Ark.		X-L	X-L	X-E	
4	Colo.				X-L	X
5	Conn.		X-L	X	X	
6	Del.					X
7	Fla.		X-L		X	
8	Idaho	X-L				
9	Ill.		X-L	X-E		
10	Ind.			X		
11	Kan.	X-L		X		
12	Ky.					X
13	Me.					X
14	Mass.			X-L		X
15	Minn.	X-L		X		
16	Mo.		X-L	X		
17	Mont.			X-L	X-L	
18	N. H.					X
19	N. J.			X		
20	N. Mex.	X-L			X-E	
21	Nev.				X-L	X
22	N. Car.			X-E		X
23	N. Dak.					X
24	Ohio.	X-L				
25	Okla.	X-L				
26	Penn.		X-L	X		
27	R. I.			X		
28	S. Car.				X-L	X
29	S. Dak.			X		
30	Tenn.	X-L		X		
31	Texas	X-L		X		
32	Utah					X
33	Va.	X-L		X		
34	W. Va.			X-L	X	
35	Wis.	X-L		X-L	X	
36	Wyo.			X-L	X	

Legend: X, General Practice; X-L, Limited Practice; X-E, Extensive Practice.

sludge up as a business, the cost of drying by make-shift methods and by grinding it by hiring a portable grinder was prohibitive."

Solving Problems

In order to come up with some suggestions for solving the marketing problems, let's examine some successful municipal operations where sales are increasing. You've already read the story about Schenectady, New York. Boise, Idaho is another good area where "excellent acceptance of the product has been promoted," according to plant superintendent A. J. Wahl. Following are our questions, Mr. Wahl's answers:

1. Do you have any research reports or general experience of gardeners and farmers who have used the sludge (B I Organic—3½ per cent nitrogen)?

Farmers are the largest consumers. One purchased 100 tons, ground to his specifications. Last year the normal silage (corn) per acre was 18 tons. The average where B I Organic was used in the seeding operation of corn planting was 27 tons of silage. Other uses by local gardeners include landscaping, lawn and shrubbery planting.

The Department of Agriculture has made analyses of the dry marketable sludge. All their analyses as to nitrogen content show that material contains ½ to one per cent above guaranteed figure on bag.

2. What kind of sales promotion efforts do you make?

We have not prepared any promotional literature or done any local newspaper advertising. Practically all retail outlets handle B I Organic locally and sell the same as a soil conditioner.

3. Do you have any suggestions based on your own experience on how the marketing of sludge could be improved and made more profitable to cities?

Here are some suggestions:

a) interest local farmers to use on such crops as hay, grain and corn;

b) interest local gardeners and greenhouse operators to use in putting in new lawns and transplanting trees and shrubbery for local trade;

c) all sludge to be sold in small amounts, as per sack. Sell through local distribution agencies;

d) sell direct to all users in ton or more lots—ground and in bulk to lower the unit price;

e) interest home builders and landscape architects in putting in new lawns and shrubbery;

f) interest the general public to apply product on existing lawns in the months of December and January. During this time, the winter snow and moisture will carry the nitrogen value to the root growth—eliminate any perceptive odor and exhilirate lawn growth in the spring.

Importance of Merchandising

The Soil Booster Corporation has been marketing sludge in the Oklahoma City area using the trade names, Soil Booster and Start-Rite. Sales Manager Ray E. Penn makes the following observations about marketing conditions:

"The marketing of sludge-type products hinges on selection of certain types of individuals as dealers. Of course the first consideration is knowledge of the dealer regarding plants and their requirements. Second consideration — good merchandisers. And last but not least, continuous striving on the part of the company for more and better information to be supplied to the dealer.

"Unfortunately, efforts in the past have been based upon products which do not meet the demand of the public. The first factor is that of reduction of odor, which can be controlled only by proper digestion and processing. The second requirement is that the customer wants faster growth than can be stimulated by sludge alone. Therefore, it is necessary to fortify many sludges in order to get the results they demand, and much educational work must be done in order to overcome the prejudices of the people

regarding this material because of its source.

"Another factor, in some cases at least, is the opposition of the public officials themselves. Another factor to be considered is the misinformation regarding the nutrition of plants and the so-called necessity of balanced fertilizer. Under this category we would also include the lack of knowledge and information regarding the soil, the function of the mineral elements, the function of enzymes, organic acids, antibiotics and other compounds necessary to plant growth. And might I say, in this connection, that it is necessary to lead people into the purchase of organic fertilizers by gradual methods, even though we know it is best."

How Much to Charge?

The retail price depends, of course, on the nutrient content of sludge produced, costs of producing it, and demand. Costs range from 25 cents per 100 pounds, not bagged (N—2.5 per cent, P—1.5 per cent) for Roanoke sludge to 3.15 retail price for an 80 pound bag of Boise sludge.

In Boise, the sludge is contracted to a local company. The sale price to the city is 40 cents per cubic yard as taken dry from the sand drying sludge beds.

Table 1 lists prices charged by various municipal plants.

Amounts to Use

The city of Marion, Indiana has printed an excellent little pamphlet which includes the following suggestions for using sludge as a fertilizer and soil builder:

"(1) For starting new lawns—prepare the seed bed by mixing the sludge with the soil. A maximum dosage of one part sludge to two parts soil may be used if the soil is of a heavy clay texture. Spade the ground to a depth of at least six inches making sure the sludge is thoroughly intermixed with the soil. Never have layers of sludge and layers of soil in the seed bed.

"(2) For feeding well established lawns—the sludge should be applied in the winter and early spring months when the ground is frozen. The lawn may be covered with a layer of sludge one-half inch deep during the cold months of December, January, and February. This cover will provide an insulation to protect the grass roots from the harmful effects of freezing and thawing during this time of the year. In addition, ample plant food will be made available for a luxuriant growth of grass in the spring.

"(3) For reconditioning old lawns—on yards or portions of yards where the soil has been too poor to support an average growth of grass, it is recommended that the procedure under (1) above be followed. It should be remembered that grass roots grow into the soil to a depth of six or seven inches only when the ground is of such a composition that will permit this growth. To top-dress and seed a section of ground that has not been properly prepared is a waste of time and money.

"(4) For gardens and farm land—sewage sludge provides an economical means of replenishing farm and garden land with nitrogen, phosphorus, and humus material. It should be put on the land just previous to the fall or spring plowing and cultivated in to the soil. The sludge cake may be applied as a manure to farm land at the rate of ten to fifteen tons to the acre. The weight of the sludge is approximately one ton to the cubic yard. It will be sold at a price far below that of any commercial fertilizer now on the market.

How to Use Sludge

In his report, "Digested Sewage Sludge as a Soil Conditioner and Fertilizer," Mr. Van Kleeck writes the following on how to use sludge:

"Sludge may be applied as a top dressing in the case of trees or lawns; in the hill in the case of melons, squash, or other vine crops; or spread, then plowed or spaded into the soil. When used as a top dressing, it should not be applied too thickly, especially on lawns, or it may choke the growing vegetation. Sludge may be applied when the ground is frozen or covered with snow. In such cases it is raked and pulverized into the soil in the spring.

"The pH of heat-dried activated sludge is low, generally averaging 5.0 to 6.0. Air-dried digested sludge after a short period of storage will normally show a drop in pH to about 6.0. Digested sludge cake conditioned with lime for vacuum filtration has initial pH values ranging from about 10.2 to 11.2, but this drops rapidly when it is mixed with soil or more slowly on storage, as a result of loss of amonnia. Tests show that pH of lime-conditioned sludges drops to about 7.5 in two or three days so that the danger of too alkaline a soil should not occur from the use of such sludge. Furthermore, experience shows that the continued use of any type of sludge unless previously conditioned with lime requires the periodic addition of lime to the soil to prevent harmful acidity.

How Safe Is Sludge?

". . . A special committee of the Federation of Sewage and Industrial Wastes Associations reporting on the "Utilization of Sludge as a Fertilizer" states: "The committee knows of no case of sickness traceable to the use of digested sludge or activated sludge."

In the U. S. Dept. of Agriculture report by Dr. Anderson on sludge he writes: "Activated sludges need heat-treatment before use as fertilizer. Such treatment is normally provided for material to be marketed. The heat used for drying normally accomplishes the destruction of dangerous organisms. This means that properly heat-dried activated sludges may be used with confidence regarding their safety from a sanitary standpoint. . . .

"It seems that States have generally accepted the conclusions of the Committee on Sewage Disposal of the American Public Health Association that heat-dried activated sludges are satisfactory from a sanitary standpoint, and that digested sludges are satisfactory except where vegetables are grown to be eaten raw. All danger is thought to be removed by action in the soil after a period of about 3 months during a growing season."

What About Results?

Table 2 shows the replies received from state officials concerning the experiences of cities that have been marketing sludge.

Here's what Mr. Van Kleeck says about the results of adding sludge to the soil: ". . . Sludge is particularly adapted to lawns. Sludge deepens the green color of grass and stimulates a luxurious growth. Its benefiits seem noticeable for several years. It should be applied late in March and again if desired early in September.

"The home owner may well use it for the flower garden. Here it provides a much needed humus for the hot summer months as well as a moderate but long yielding amount of nitrogen.

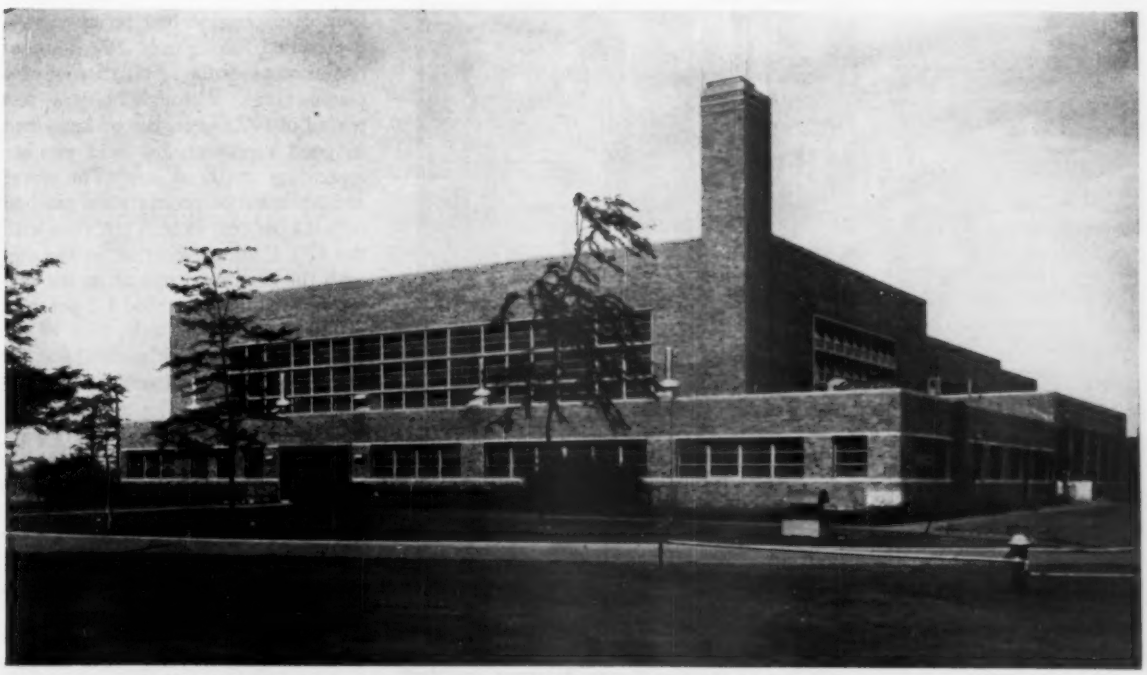
Oil Filters on Sludge Gas Engines

The Hunts Point Pollution Control Project is powered mainly by four Cooper-Bessemer Type LS-8-GD 900 hp dual fuel engines. Two of the engines are direct connected through pneumatic clutches to drive 675 Kva generators or 21,000 cfm blowers. The load and air demands are such that three engines are required nearly 100 per cent of the time, the plant service factor for 1957 being 0.713. The engines are operated at full load a large part of the time, the capacity run factor for 1957 being 0,803.

The fuel used is digester gas (approximately 65 per cent methane and 35 per cent CO_2 with trace of H_2S) and No. 2D fuel oil in the ratio of about 9 per cent oil to 91 per cent gas on a Btu basis.

Before

The lubricating oil used since initial operation in 1952 has been a manufactured "Brand" quality mineral oil. The equipment originally installed to



AT THE HUNTS POINT sewage works in New York City the new oil filters are in use.

In May, 1952 the 120 mgd. "step aeration" activated sludge plant at Hunts Point was placed in service. This project collects sewage in the Bronx from the Throggs Neck area on the upper East River to the junction of the area tributary to the Wards Island project. Generally, it serves the central and east portions of the Bronx covering 24.4 sq mi, an area roughly seven miles long north and south and about four miles wide east and west.

Located on the East River at Barretto Point near the foot of Coster Street, the Hunts Point Plant occupies a site of 25.5 acres. Of the total cost of $22,258,000, the 7.8 miles of intercepting sewers required were responsible for an expenditure of $5,670,000. The Throggs Neck Pumping Station built in connection with the project cost $350,000. The intercepting sewers range in size from 42-in. diameter to barrels 12 by 10 ft.

The Hunts Point Works eliminates pollution not only along the Bronx shore from Eastchester Bay to 149th Street but also along the North shore of Queens, from Great Neck to Flushing Bay. The 12 sewer outlets which formerly dumped sewage from the Bronx into the waters of the upper East River affected Queens as well as the Bronx, because winds and tides carried waste matter over to the Queens side. Since the Hunts Point Project went into operation a marked improvement has been noted in the waters of the upper East River and of Eastchester Bay.

service and maintain the oil was a 55 gallon batch type oil refiner, two 100 gallon per hour centrifuges, and each engine was supplied with two cartridge type bypass filters and one series type full flow filter. The bypass filters clogged after about 600 to 700 operating hours, requiring renewal of the throwaway cartridges. This operation entailed the drainage of the oil from the filters and the replacing of 14 units in one filter and three units in the other. Two man days' labor were required.

Experiment

A new type of bypass filter, the Norse Electric C J C Number 35 Finefilter was installed and put into operation May 31, 1955, in the lubricating oil system of No. 1 Engine for a three-months' test period. (The design of these filters is shown in accompanying illustrations and diagram.) Engine No. 1 had had 15,958 hours of operation without a piston ring overhaul.

Oil was changed on May 31, 1955, the regular bypass filters cut out and the C J C filter cut in. The normal centrifuge schedule was continued, approximately 800 gal per day being passed through the centrifuge from each running engine. No. 1 engine was loaded with a generator throughout the test at approximately full load for 18 hours and 0.6 load for the other six hours of each day.

Determinations of water and sediment, precipitation and acid number were made periodically on samples of the oil in the engine.

No. 2 engine was operated under similar conditions, using the cartridge type filters and being loaded by a blower at about three-quarters load for twenty-four hours a day. This engine was chosen for comparison because the total hours of operation since installation, without change of piston rings, was 14,900 as compared to 15,958 for No. 1 engine. The oil was changed and the filter units renewed before the start of the test.

The tests with the C J C filter on No. 1 engine and the cartridge type filters on No. 2 engine were conducted as follows: After the acid number reached 0.9 the oil was changed; when the filter was loaded it was cleaned. These changes were as follows:

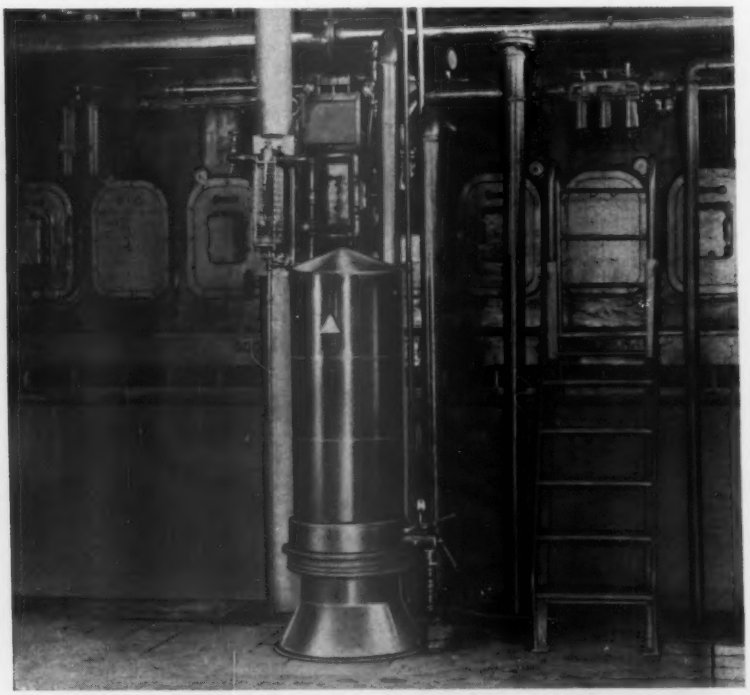
Test Hours	Oil Changed	Filter Cleaned
700	#2 Engine	#2 Engine
944	#1 Engine	
1520		#1 Engine

The C J C test filter was cleaned and then installed on No. 4 engine for another test run of one month's duration. This engine had recently been overhauled, having only 2971 hours of operation since the installation of new piston rings. Throughout this test period of 672 hours, the oil remained in good condition, the acid number remaining at 0.6 or less. The water and sediment or precipitation reached only 0.1 per cent in both test runs with the C J C filter, whereas in the run with the cartridge-type filter, the water and sediment reached 1.2 per cent at 700 hours.

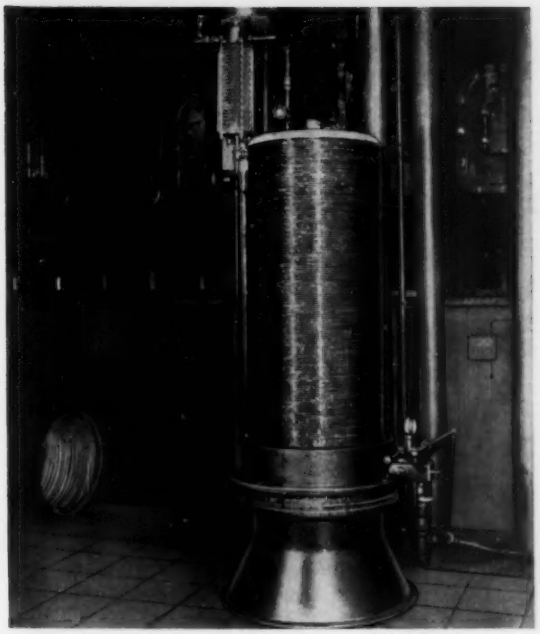
As a result of these tests, C J C filters were purchased and installed on all of the engines. The test filter was left on No. 4 engine. New filters were installed as follows: No. 1 and No. 5 engines on Aug. 2, 1956, and No. 2 engine on Feb. 21, 1957.

After

Since these filters were installed, records have been kept of their operation. They have been cleaned a total of fifteen times to June, 1958, with an average period of 2743 engine hours



CJC FINEFILTER installed alongside one of the four Cooper-Bessemer duel fuel engines at Hunts Points sewage works.



OIL travels along the edge of the filter discs at the rate of 60 gal per hr. This unit is shown with the dust cover removed. Dust cover is at left.

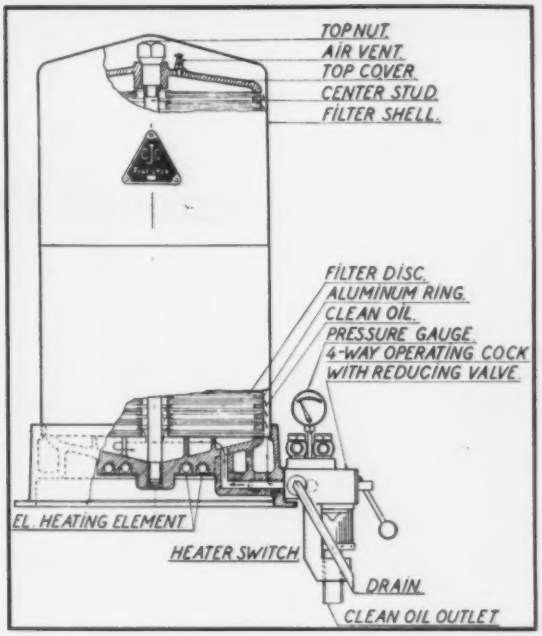


DIAGRAM shows construction and provision of electrical heating arrangement when engine is not running or when filter is some distance from the engine serviced.

between cleanings. A total of 4500 filter skins have been used and 751 filter discs, or an average of 300 filter skins and 50 discs per cleaning. The labor required is four man days per cleaning. The cost breakdown is:

Per cleaning—			
300 filter skins	@	.374 ea.	$11.22
50 filter discs	@	1.98 ea.	99.00
4 man days labor	@	17.60	70.40
			$180.62

Filter maintenance cost per engine hr.

$$\frac{180.62}{2743} = \$0.0658$$

The cost of operation of the cartridge-type filters based on 700 hours between cleanings was:

Per cleaning—			
14 cartridges	@	4.96 ea.	$69.44
3 cartridges	@	6.25 ea.	18.75
2 man days labor	@	17.60	35.20
			$123.39

Filter maintenance cost per engine hr.

$$\frac{123.39}{700} = \$0.1763$$

The savings in filter costs using the C J C units is therefore $.1763 — $.0658 = $0.1105 per engine hour.

Since the yearly engine hours in this plant average 25,000, the annual savings in filter cleaning costs is

$25{,}000 \times .1105 = \$2{,}762.50.$

Oil Saved Too

A check on lube oil consumption showed a saving in oil since the installation of the last C J C filter. The average consumption for the years 1954 to 1956 inclusive was 787 gal per month as compared to the average for the year ending Feb. 28, 1958, of 657 gal per month, or a reduced consumption of 130 gal per month. This consumption is, however, affected by the condition of the piston rings, as well as other factors.

Since the installation of the last C J C filter, it has been found that very little dirt is removed by the centrifuge, the use of which is now solely to detect and remove water from the oil. Water is detrimental to these filters, and it was necessary to clean No. 5 filter and renew all the discs after a water leak on No. 5 engine.

As was indicated by the original test runs, the control of the acid number depends on the condition of the piston rings; the nearer the time for an overhaul, the more frequently is it necessary to change the oil. There is approximately a 10 per cent loss in the refining of the used oil.

It has been the practice to weigh the dirt removed from the filter when cleaned, and the average was 107 lb per cleaning or 107 lb for every 2743 hours of operation.

The cleaning operation is not difficult and is easily finished in four man days. Care must be exercised in the handling of the discs since these are used for more than one operation of the filter. They should, however, be discarded after two or three runs. It was found that, if the filter disc pile was tightened down too tightly after cleaning, the flow of oil was greatly restricted and would stop completely in a short time. It is better, therefore, to maintain a pressure on the discs just enough to prevent leakage past them.

The filters are located on the engine-room floor at the engines, and the discharge from the filter is by gravity to the engine sump tank. They can be inspected during operation by removing the dust covers.

As a result of the experimental study and the installation of this new type of filter, the operating cost of power phase of the Hunts Point Plant were materially reduced and operations improved.

Underground Photographic Surveys

by CHARLES H. SORTOR
Manager, Laval Underground Surveys, Fresno, California

For years the biggest problem in the repair and maintenance of deep wells and sewer lines has been the exact location and nature of the failure. Often entire sewer lines had to be excavated in order to repair a very localized failure. The situation with regard for deep well failure was even more critical. No excavation was possible; therefore, all repair work had to be by guesswork. These troublesome problems no longer exist, however, due to the ingenuity of Mr. Claude C. Laval, Jr., who has developed a stereo camera for photographing, in place, deep wells and sewer lines. This development is a significant one in the field of underground surveying.

History

There are more than 50,000 water wells in the San Joaquin Valley of California, varying in depth from less than 100 feet to more than 3,000 feet. They penetrate the deep alluvia of the valley floor and produce more than 9,000,000 acre feet of water each year for irrigation, industrial and domestic use.

Relatively little trouble has been experienced with the shallow wells. Many of these wells have lasted as long as forty years, and their average life expectancy could probably be set at thirty years. But the record of the deep wells has not been as good. Average life has been ten years or less. Some of them have developed casing breaks during the first month of use. In some areas the life expectancy has been as low as five years.

In 1945 and 1946 Peerless Pump Division in Fresno, California, undertook a study of the problem of well failures. Throughout the study it seemed that the greatest difficulty lay in the fact that actual field conditions could not be duplicated in the laboratory and there was no way to see what went on in a well.

In 1947 the problem was taken to a man named Claude C. Laval, Jr., with a request for a camera which might be lowered into wells to photograph their interiors.

He went to work at once and soon had a camera which worked fairly well. After a year or so of perfecting, he was able to get good pictures which could be viewed in three dimensions and had applied for patents on the basic feature which made well photography possible, see Figure 1. His pictures soon showed the causes for deep well failures and made repairing a simple matter.

FIG. 1—CAMERA ready for lowering into well.

Well Photography

There are three common types of well failures, all of which show up very well with the Laval camera. These are: (1) axial compression failures, (2) parted casing failures, and (3) casing collapse failure.

Axial compression failures usually follow the same pattern. Tiny peripheral wrinkles first appear. Some portions of the wrinkles grow more than others and generally from three to six progress to the point of rupture. Some of the ruptured portions of the casing are intruded into the well and some extruded. The total length of the deformed section is usually from one to four feet. The casing may break at one elevation on one side and at a different elevation on the other. This usually causes a "dog leg" and the axis of the section of casing between the two breaks becomes misaligned with the axis of the well. Working "blind" in this type break with old fashioned percussion swages, the well repairman usually broke through the casing wall and ended up with a big repair bill and a ruined well. When the exact nature of the break is known, however, repair is usually easy, see Fig. 2.

Photographs sometimes show casings parted at the welds. When this is the case, the zone of break is usually carefully photographed with a side wall camera to show the nature of the break and the length of separation between the two sections of casing. With this information, it is a simple job to place a liner over the break.

When the failure is due to casing collapse, the camera shows the degree of ovaling and whether or not the casing has ruptured as a result of the collapse. Frequently, the collapsed casing can be straightened out and returned to its original roundness. Working without photo information makes this simple repair job nearly impossible.

FIG. 3. SWAGE being swung into position for repairing 18" water well.

Casing Repair Tool

For repairing all types of casing breaks and distortion, a companion tool to the Laval well camera is the Laval electro-hydraulic swage, Fig. 3. This patented tool can be run on pipe or wire line and can quickly and safely straighten out compression wrinkles, breaks and ovals. Torn sections of casing can be pushed back into place so that liners can be driven tightly into position. It can be preset to give a definite diameter, so that the repairman may expand the damaged section beyond its normal diameter or he can leave any desired amount of "spring back" to hold the liner in place. The swage can also be used to "crimp" liners in place or to bell out to shut off sand and water which might leak past the upper or lower end.

FIG. 2—BEFORE: This compression break in a 16" x 15" casing is above the static water level. But water from a shallow aquifer is running into the well and falling 100 feet to the water level, trapping and entraining air and lowering pump capacity.

AFTER: Here's a photo of the same casing shown above after a Laval swaging job, ready to receive a press fit liner. Result: Water was shut off and well went back on pump, good as ever.

Supplementary Uses of Well Photography

One use of photo logs that is becoming more popular is as a part of the well acceptance test. This is advantageous to the driller as well as to the client since it provides positive proof of the use of proper materials and workmanship and releases the driller from responsibility. Another use is the detection of minor well defects such as plugging of perforation slots

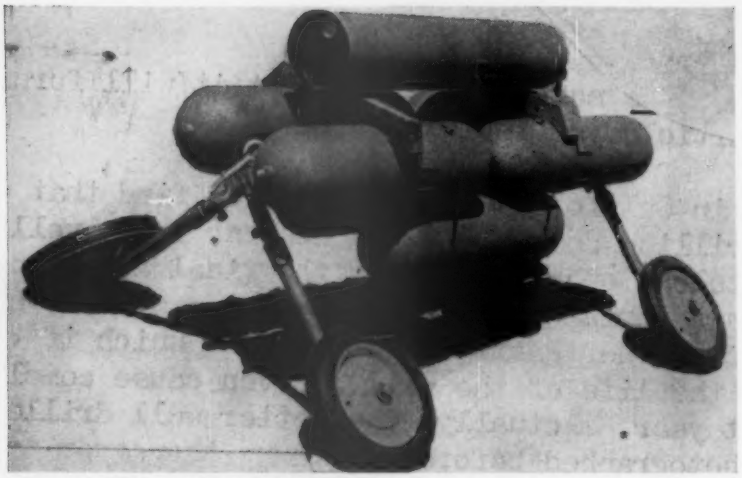


FIG. 4. TROUBLE SHOOTER camera and carriage can be used in six inch and larger diameter horizontal and inclined sewerage and pipe lines.

by calcium deposits or the growth of barnacles over the perforations. Any of these minor troubles can be more easily and quickly treated if the exact nature of the trouble is known. A final use of well photography is in connection with a preventative maintenance program. As well pumps are removed for repair, the wells are photographed from top to bottom and the photo logs are placed on file for comparison. Any defect can thereby be noticed as it develops, and repairs can be made before the trouble is serious. This results in long well life and less down time for major repairs.

Sewer Photography

The application of this technique to sewer maintenance is a valuable one. In this case the camera is mounted horizontally, usually on wheels, Fig. 4. The camera is operated electrically through a trailing cable, and the six air tanks keep the equipment from falling in any hole or getting stuck on an obstruction. When lines smaller than six inches are to be surveyed, the camera is removed from the wheels and placed on a sled. The camera on sled or wheels, is placed in the sewer at a manhole and pulled up to the next manhole by a cable connected to a winch. If necessary, the camera contains enough film to photograph 3/8 of a mile when taking pictures every five feet. The camera can travel 10 to 20 feet per minute and can take pictures every 15 seconds. As with the well camera, the pictures are stereo photographs.

Uses of Sewer Photography

The advantages for this type of operation are many; one of the most important being that no man need risk his life or expose himself to the possibility of bodily harm in making sewer inspections. Another advantage is the accurate detection of any structural failure. Not only is the defect exactly located, but its nature is clearly revealed. This greatly aids repair work by peventing much unnecessary digging. Small lines could under no circumstances be inspected by a person; expensive digging would be the only positive alternative to photography. One disadvantage of this method is that unless the sewer line can be dewatered by bypassing the flow, only the portion of the sewer above the sewage level can be viewed.

Three of the common defects other than collapse which can be easily detected by this type of underground survey is the infiltration of ground water, when the ground water table is above the sewer pipe, the intrusion of roots and the accumulation of grease. Fig. 5 shows cases of the latter two problems in an 18" sewer line. When ground water is flowing into a sewer, it is almost impossible to determine the point of inflow except by viewing the line from the inside.

Sewer photography, as in the case of well surveys, can be used an as effective preventative maintenance program as well as being used for final acceptance inspections of new sewer lines.

Summary

The use of photography for underground surveys in the field of well and sewer line maintenance by the Laval Underground Surveys Company has saved millions of dollars by taking the guesswork out of repair. With the Laval camera, the problem can be exactly located, and its cause accurately identified. Once this is done, a potentially large job becomes a small repair operation.

FIG. 5. GREASE in foreground encrusted in 18" sewer. Note roots growing through defective joint. White card in background being held through manhole is a convenient method of recording date and section of sewer.

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Sewer Cleaning and Safety Measures

by NORMAN W. NESTER
Civil Engineer Physical Plant Department, University of Illinois, Urbana, Ill.

Municipal responsibility for maintaining sewers has long been a question in the courts. However, keeping sewers clean is not a governmental function, according to a recent legal decision in Oklahoma. Nevertheless, a few localities have laws making sewer cleaning mandatory and exempting them from damage liability, although most municipalities do maintain their sewers in good repair, because this is regarded as a proprietary, rather than a governmental function.[1]

Adequate maintenance of sewers, although not a government function, becomes a very important tool in a good public relations program. Good public relations are a necessary function of any governmental agency, and good performance is essential to public relations.[2]

What Causes Stoppages

Operational failures or stoppages in modern sewers usually arise as a result of poor installation, root growth, grease, or introduction of uncommon materials and debris of such size as to cause clogging.

Employment of a qualified engineer in the planning, developing, designing, and construction of a sewer system will eliminate many failures which can normally be attributed to faulty installations.[3] Rigid inspection during construction will eliminate subsequent joint failures, with resultant savings in maintenance requirements.

In most cases, sewer clogging is a gradual occurrence, and a planned cleaning program will reduce the number of complete stoppages. Obstructions found in sewers may be classified in four general categories, as follows:

1. Materials that can be flushed out of the sewer, such as sand or grit.
2. Greases and slimes that adhere to the sewer walls.
3. Bricks, metals, and other materials not normally found in a sewer.
4. Tree roots.

Flushing Procedures

Flushing is accomplished by producing in the sewer a stream of water with sufficiently velocity to produce turbulence. Fushing loosens the sediment, places it in temporary suspension, and then moves it out of the sewer. Thus, sufficient flow must be produced to move the material to a section of sewer that has sufficient velocity to scour and keep itself clean. Where grades are flat or sewers lack the necessary velocity, the flushing process must be repeated in successive sections downstream from the trouble-some section as far as required to remove the material.

The simplest method of flushing is through use of hose and water from a fire hydrant, and the hose may even be condemned hose from the fire department. To prevent pollution of the water system, which might occur as a result of negative water main pressures, there should be a vacuum breaker on the fire hydrant used in flushing. To prevent the water from flowing upstream in the sewer during the flushing operation, there are available bags which can be attached to the front of the hose with a nozzle on the outlet. The bag expands as water is introduced and prevents the water from backing up.

Other devices for flushing with hose are: (a) a nozzle with small jets directed upstream with sufficient force to propel the flushing nozzle downstream, and (b) a nozzle which rotates blades in front of it as it is moved down the sewer.

Flushing with sewage is also a common practice. This can be accomplished by plugging the sewer at a manhole and permitting the sewage to surcharge before removing the plug. The same effect can be created by introducing into the sewer above the stoppage a beach ball or elongated bal-

Schedule of Maintenance Work Sanitary Sewer Locations

	Location	From	To	Size	Items to be done
		Mathews Ave. Lateral			
1	Mathews	Green	Illinois	8"	3, 4, 5
2	University Men's Club Lateral			6"	4
3	Mathews & Illinois Depressed Section			2-8"	2, 3
4	Mathews	Illinois	Nevada	8"	3, 4, 9
5	Noyes Lab. Depressed Section			2-6"	2, 3
6	Chemistry Annex Depressed Section			2-6"	2, 3
7	Agronomy Greenhouse Depressed Section			2-6"	2, 3
8	Observatory Lateral			8"	4
		Green St. Lateral			
1	Green	Goodwin	Mathews	2-10"	9
2	Mechanical Engineering Laterals			6"	4
3	Green	Goodwin	Kings Hwy.	10"	3, 4, 6
4	Physics Laterals			6"	4
5	Natural History Lateral			10"	4
6	Civil Engineering Lateral			6"	4
7	Green	Mathews	C. E. Hall	10"	3, 4, 5
8	Illini Union Lateral			8"	7
9	Green	MH Eng. Hall	Burrill	10"	3, 4, 5
10	Altgeld Hall Lateral			8"	4
11	Green	Burrill	Wright	10"	3, 4, 5
		Wright St. Laterals			
1	Wright	Boneyard	Green	10", 12"	3, 5
2	Siphon on Wright at Boneyard			2-8"	2
3	Electrical Engineering Lateral			2-6"	4
4	Arcade Buliding Lateral			6"	4
5	Illini Hall Lateral			6"	4
6	Y. W. C. A. Lateral			6"	4
7	Davenport House Lateral			6"	4
8	1007 Wright Lateral			6"	4

FIG. 1—SAMPLE entries from a schedule of maintenance of sewers at the Univ. of Illinois: Numbers in right hand column indicate work to be done (see Fig. 2).

loon, which is floated down to the point of stoppage. There it elongates, permitting the sewage at increased head to by-pass it and thus loosen the obstruction through "jet" action. There are a number of devices of this type on the market.[4]

Rodding Cable Procedures

Grease stoppages are removed by either rigid or flexible rods. There are a number of tools and appliances which can be attached to the rods for cleaning purposes. These include wire brushes (porcupines), corkscrews, cutters, scoops, hoes, augers, serrated blades, and coils. House service sewers are cleaned by introducing a rotating rod, cable, or coil, with the previously mentioned devices on the front end of the tool. Where grease stoppages are a continuing problem, a program of periodic maintenance should be followed.

Winches or windlasses capable of pulling cleaning devices through the sewer may be used to remove heavy and bulky materials. A number of manufacturers produce this type of equipment.[4] The devices pull through the sewer cables with attached buckets of slightly smaller diameter than the sewer. The windlasses are either hand-operated or power-operated and will function with buckets of various sizes. Because of high cost, this type of equipment is usually found only in the larger cities. The winch-type cleaning device also may be used to remove sand and other settleable solids.

Root Removal

Of all the problems facing a sewer cleaning program, clogging by root growth is perhaps the most serious and most common. Although most stoppages are usually removable by flushing, root removal can only be accomplished with cutters or chemicals. Cutters and augers generally are power-operated.

Some municipalities have reported success in root removal by adding copper sulfate to the sewage.[5] Other chemical compounds that claim the control of root growth also are available.[4] Where tree or shrub roots are clogging a sewer, and produce continuing stoppages, it may be necessary to remove the tree. Care should be taken in making decisions for removal, because litigation may result.[6]

Both Curative and Preventive

Sewer cleaning and maintenance is, or should be, an important function in the work program of a municipality. Maintenance can be either curative or preventive. When maintenance is deferred until a breakdown or stoppage occurs, it becomes curative. When a department anticipates stoppages and cleans prior to the stoppage or breakdown, the service is termed preventive.

A preventive program of cleaning and maintenance will reduce stoppages

ONLY ONE CAN DO THEM ALL!

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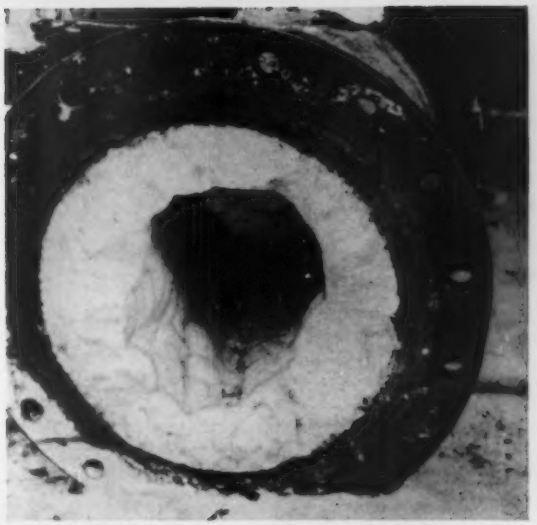
Sewers clogged? Water mains obstructed? Whatever it is . . . no matter how bad it is . . . N.P.R.C. can clean it faster, more efficiently and at lowest cost . . . with results backed by N.P.R.C.'s famous IRONCLAD GUARANTEE.

Only N.P.R.C. dares make this statement. It is possible because N.P.R.C. uses specially built, patented POWER equipment that has been proven in countless pipe cleaning jobs throughout the country. This equipment is manned by highly trained crews who know the pipe cleaning business. The crews are guided by experts whose only business is pipe-cleaning . . . men who have solved many problems and know the unique N.P.R.C. modern methods of pipe cleaning.



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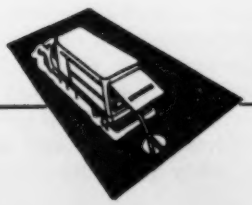
Many municipalities with recent soft water installations have found the outer surfaces of the encrustations and tubercles are dissolving and presenting the problem of rusty water. N.P.R.C.'s new, modern methods thoroughly clean water mains . . . not just opens them temporarily. Because of these maximum results, N.P.R.C. guarantees complete removal of rust in the mains cleaned . . . 100% elimination of rusty water backed by the famous N.P.R.C. ironclad guarantee.

LARGEST SEWER MAIN PIPE CLEANING ...WITH AN IRONCLAD GUARANTEE

FOR FREE FACTS, SURVEYS AND ESTIMATES ON YOUR PROBLEM CALL CHICAGO, MOnroe 6-7700, OR WRITE OR WIRE. No obligation, of course.



NATIONAL POWER RODDING CORPORATION

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Sanitary Sewer Maintenance Schedule, University of Illinois

	Item Description	Item Number (by Frequency)* M	Q	S	A
I.	Make general inspection of entire system and prepare notes on manhole examinations, as follows:	—	—	—	3
	A. Odor of gasoline or presence of oil slick on surface of sewage.				
	B. Obnoxious or explosive gases.				
	C. Evidences of sand, grit, mud, or other debris.				
	D. Sluggish flow, septic sewage, or accumulation of sewage solids.				
	E. Excessively diluted flow.				
	F. Structural failures, including cracked or faulty masonry, incorrect grade of manhole cover, unsound manhole steps, and damaged, cracked or improperly seating covers.				
II.	Inspect manholes during heavy storms for excessive infiltration.	V	V	V	V
III.	Rod, cut, brush and/or flush entire sewer system.	—	6	9	5
IV.	Clean upper ends and flat grades.	—	1	—	—
V.	Clean inverted siphons and depressed sections.	—	2	—	—
VI.	Clean sluggish building lateral sewers.	8	7	—	4

*M=monthly; Q=quarterly; S=semi-annually; A=annually; V=varying, dependent on weather.

FIG. 2—ITEMS of work included on a maintenance schedule.

that may provide health hazards, property damage, and expensive major repairs. During World War II, the U. S. Army placed great emphasis on preventive maintenance and produced manuals for many types of operations, including sewers and sewage treatment.[7] An instruction text from the Illinois State Department of Health follows the general pattern of the Army program. A preventive maintenance program in sewer operation has been proven to be economical while providing an efficient service to users.

The Physical Plant Department of the University of Illinois has had a preventive maintenance program in both building maintenance and sewer maintenance for a number of years. Figure 1 shows some sample entries from a series of sheets of a schedule of maintenance performed on the sanitary sewer system at the University of Illinois. It will be noted that the sewer location, size, and limits are identified for each street. Also indicated in the right-hand column are the reference numbers for maintenance features to be accomplished. These numbers refer to items on a maintenance schedule (Fig. 2), which provides for inspection service as well as cleaning and maintenance of each sewer in the University sewer system.

Frequency of maintenance has been divided into four periods, as indicated in Figure 2. In addition to the schedules, the sewer crew is provided with 8½- by 11-in. sectional maps (scale 1 in. = 50 ft) bound in a looseleaf folder. The maps show the locations of sewers and other buried utilities. They aid the crew in coverage of the maintenance route and also locate utilities where excavation of a sewer is necessary.

Good Records A Must

A preventive program is of no value unless permanent and accurate records of the entire function are maintained. Figure 3 shows parts of the inspection and service card used by the University Physical Plant sewer crew. All data pertaining to maintenance of a sewer are kept on the cards, with a card provided for each branch sewer indicated in Table 1.

Much of the data on the face of the card can be copied from the information contained in Fig. 1. On the reverse side is recorded all maintenance completed, together with the date of completion and the initials of the crew chief. On the face of the card and at the top, the calendar months are listed. File signals are clipped to the card at the month or months during which the inspection and maintenance is to be carried out.

When the program was initiated at the University, frequencies and dates were selected by guess. As the program progressed, dates were altered and frequencies reduced or extended as needed. At present the schedule is spread throughout the year as much as possible and items are particularly designated during periods which will least interfere with other seasonal operations.

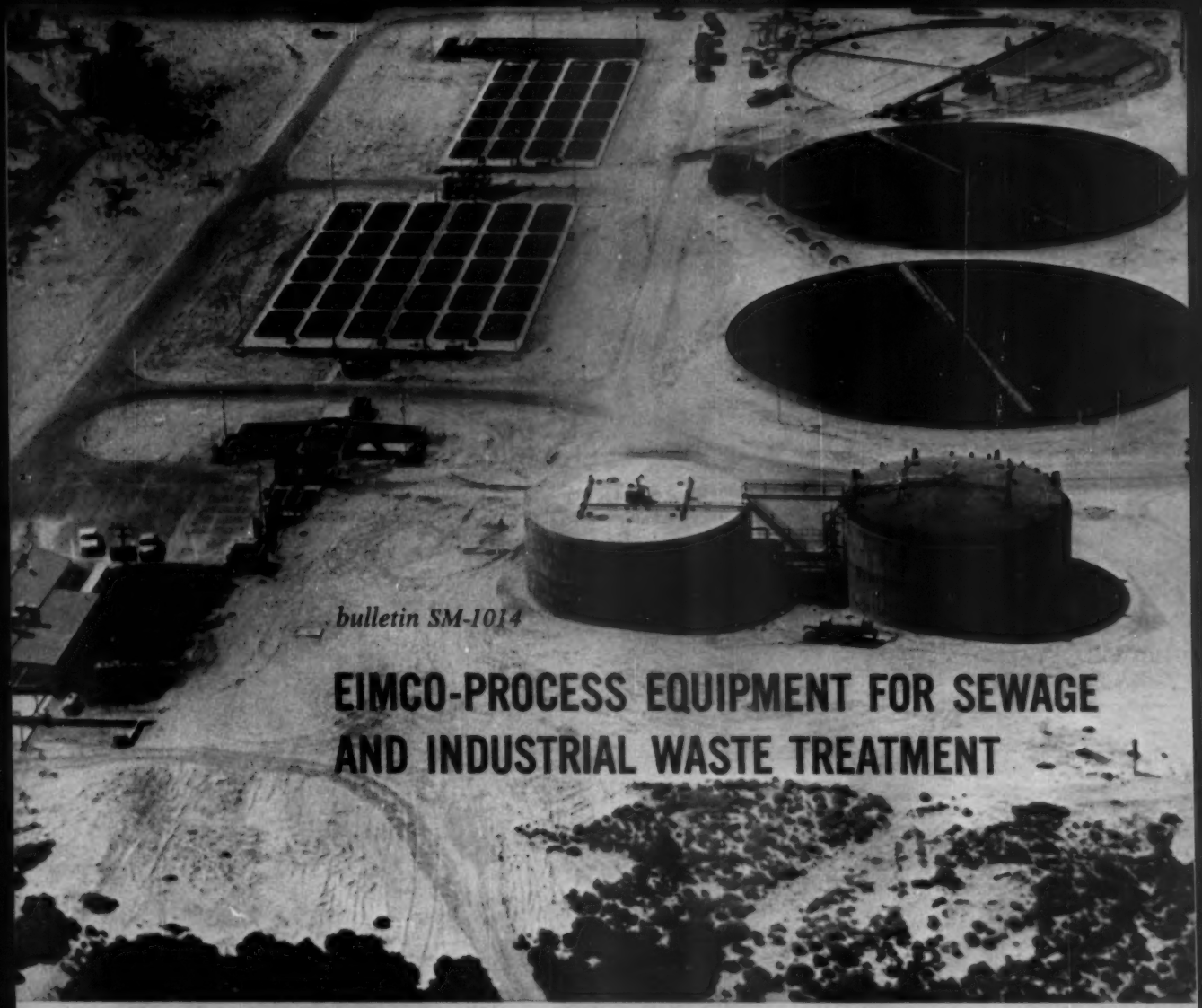
Maintenance of sewers at the University is completed by a crew of 3 to 4 men, depending on the operation. This crew is supplied with a four-wheel trailer equipped with all of the equipment and tools necessary to clean and maintain sewers.

The program as presented here, may, at first glance, seem to be quite extensive and detailed. However, it was adopted over a long period from the records accumulated as the normal function of cleaning progressed. The program covers all possible contingencies; when followed completely it provides for adequate maintenance and efficient service. Since the adoption of the maintenance plan, emergency calls have been reduced to an absolute minimum, with resultant increase in service efficiency. Furthermore, there have been no damage losses resulting from flooding since installation of the program.

The program is flexible enough to be adapted by any community and a plan similar to that utilized by the University will insure an efficient, economical operation of one of the most important services rendered by a municipal government.

Frequently, the function of sewer cleaning is provided by personnel drawn from other operations. As a result, the maintenance is haphazard and expensive installations suffer deterioration and must be replaced.

From the standpoint of safety and efficient maintenance practices, it is inadvisable to expect untrained personnel, without knowledge of the dangers involved or of the laws which regulate safety procedures, to clean



bulletin SM-1014

EIMCO-PROCESS EQUIPMENT FOR SEWAGE AND INDUSTRIAL WASTE TREATMENT

Eimco-Process equipment at the Sunrise Mountain Sewage Treatment Plant, Las Vegas, Nevada, includes three 175 ft. dia. Rotary Distributors, two Grit Separators and five Sludge Collectors. Consulting Engineer—John A. Carollo, Phoenix, Arizona.

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GRIT SEPARATORS

Eimco-Process Grit Separators combine continuous mechanical grit removal with thorough grit washing in a single compact unit. The grit is collected in a shallow square tank and moved outwardly to the washing compartment by a rotating raking mechanism. The spiral screw washer has a double pitch for thorough washing and rapid dewatering; two-deck spirals are furnished when the grit must be moved long distances vertically or horizontally. For separate grit washing or in plants with low flows, a type utilizing a conical settling tank is recommended.

CLARIFIERS

Three basic types of Eimco-Process Clarifier mechanisms are available to cover the full range of tank sizes and load requirements. These beam supported, center column or traction units operate on the common principle of moving settled solids to the tank center for removal. All feature efficient drivehead designs for minimum power consumption and heavy-duty gears and bearings for lowest maintenance costs. An Eimco-Process design innovation, the large diameter feedwell, is available for all three types. This reduces short circuiting and increases removals.

CHAIN COLLECTORS

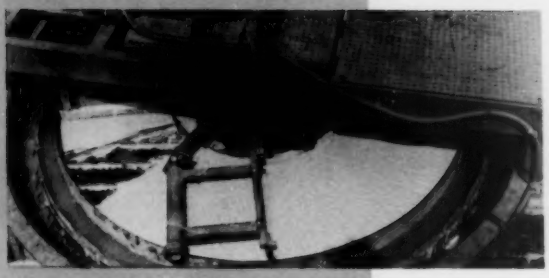
Eimco-Process chain and flight type sludge collectors are furnished for all sizes of rectangular sedimentation basins. Three types are available for light, normal and heavy duty; all feature corrosion resistant construction with Promal chain, clear heart redwood flights, helical gear reduction drive units with overload protection and the rugged Eimco-Process self-aligning "cone cap" babbitted bearings. A variety of auxiliary equipment is available, including cross collectors, rotating scum troughs, skimmers, weirs and launders.

OXIDATORS®

Developed and introduced by Eimco-Process, and with a number of exclusive features, the Oxidator combines aeration, flocculation and sedimentation in a single circular tank. Beam supported, center column and traction types feature gentle or intense aeration, adjustable sludge recirculation rates and controlled sludge thickening. The aeration keeps the influent fresh and, combined with the controlled internal sludge recirculation, increases floccule size, minimizes scum formation and gives increased suspended solids and BOD removals. A key feature of this one-step intermediate treatment unit is the annular sludge trough which permits obtainment of a concentrated sludge.

REACTOR-CLARIFIERS

Eimco-Process Reactor-Clarifiers combine coagulation and flocculation, sedimentation and sludge removal in a single tank, with aeration and sludge recirculation as optional features. These are the most compact and economical units available today for high removals in the pretreatment of sewage, secondary treatment of sewage with the addition of chemical coagulants, or treatment of various industrial wastes to condition the water for reuse. Standard rate, high rate and special purpose types are available in sizes to 200 ft. dia. and with unique features such as an annular sludge trough for improved thickening.

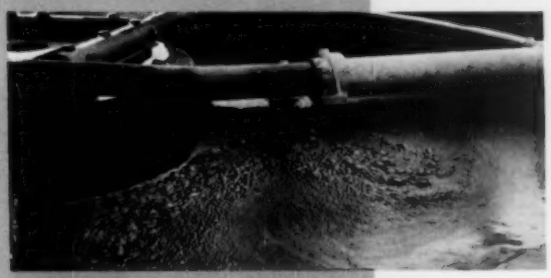


FLOTATORS

Eimco-Process Flotators are primary liquid-solids separation units utilizing dissolved air flotation principles to provide a high degree of consolidation in a small tank. By partially or totally air-pressurizing the influent and releasing it below the liquid level, both floatable solids and those which tend to remain in suspension are quickly carried to the surface for removal by skimmers. Heavier solids are removed by bottom rakes. Flotators are furnished as complete systems tailored to the job requirements and permit high overflow rates with short detention.

FLOTATOR-CLARIFIERS

Eimco-Process Flotator-Clarifiers combine flotation in a large diameter center compartment with clarification in an outer annular area. Available in a variety of types, sizes and modifications to meet specific operating conditions, they accomplish maximum removal of all types of solids in a single circular or rectangular tank much smaller than the conventional sedimentation basin. As a result of the quick, efficient removals, these units are ideally suited for plants treating sewage or wastes with widely varying flows or composition.

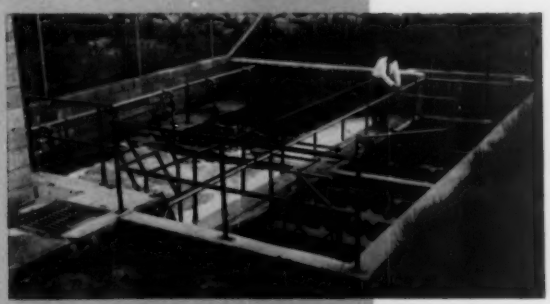


FLOTATOR-THICKENERS

Eimco-Process Flotator-Thickeners are specifically designed to handle secondary sludges that are difficult to thicken or dewater with gravity-type equipment. Combining an advanced air injection and diffusion system with heavy-duty scum and sludge removal assemblies, the Flotator-Thickener achieves dependable concentration to a fraction of the original volume. Operational flexibility is provided by a unique dual-pipe arrangement for total or partial influent pressurization. The low initial cost of one of these high-capacity units is readily justified in most plants.

ROTARY DISTRIBUTORS

Eimco-Process Rotary Distributors are furnished for all bed sizes and with influent column diameters from 8 to 60 in. Both standard and high rate types are available to provide desired flow ratios with a minimum head. Pipe arms are normally recommended for smaller flows, rectangular fabricated steel arms for large flows. With the unique radial weir center assembly and compartmented arm design, widely varying flows are handled with a minimum head loss. For less demanding operating conditions, a simple and economical center assembly without internal flow control is furnished. Leather or composition seals designed for trouble-free service are a standard feature.

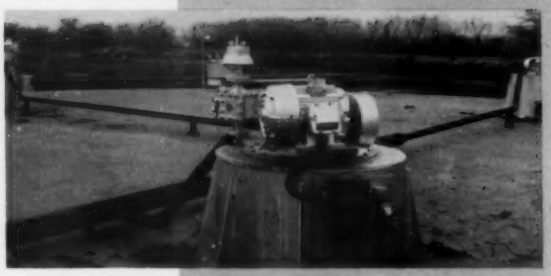


AEROBIC DIGESTION PLANTS

To the natural advantages of aerobic digestion, Eimco-Process adds the economies of prefabrication and design standardization to deliver package units low in initial cost, easy to ship and install, simple to operate and maintain. Six rectangular units cover the 3,000-10,000 GPD capacity range. Circular units are furnished in a variety of sizes to handle flows from 20,000 to 100,000 GPD. Particularly suited to small domestic sewage and organic industrial waste flows, Eimco-Process Aerobic Digestion Plants provide excellent BOD reduction and produce a clear, odorless effluent.

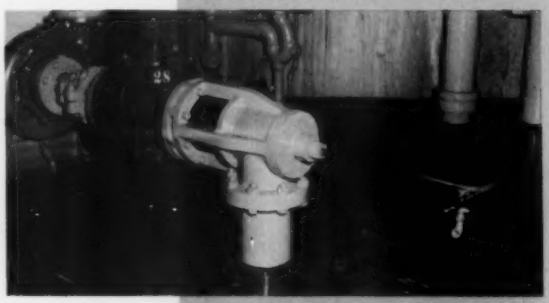
DIGESTER MIXERS

Two types of Eimco-Process Digester Mixers are furnished, a conventional unit for small, single-stage digesters, and a larger unit in sizes from 3 to 15 HP that provides recirculation capacity up to 15,000 GPM. The latter type consists of a special non-clog propeller, a stationary deflector for streamlined flow, a removable draft tube and a steel gas dome in one rigid assembly. Generously spaced upper and lower bearings compensate for the heavy thrust loads induced by recirculation of large amounts of thick scum. Various accessories are available as required.



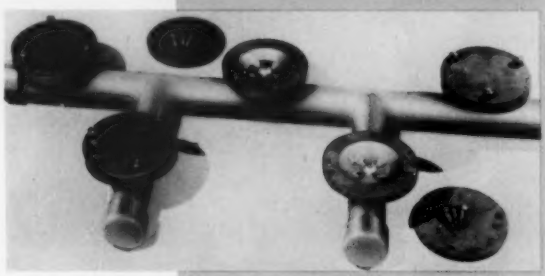
CLEANABLE SIGHT GLASSES

The Cleanable Sight Glass is an Eimco-Process design innovation providing reliable visual observation of sludges or liquor flowing inside a pipe. With their standard flanged fittings, the sight glasses can be installed in any L section of 4″ or 6″ pipe. The pyrex glass section is water-tight and carries no load or strain. It is easily cleaned on the inside surface with solvent injected through the hollow brass wiper rod, thus allowing unimpaired visual control of the plant stream. These inexpensive adjuncts to efficient plant operation have earned enthusiastic acceptance throughout the world.



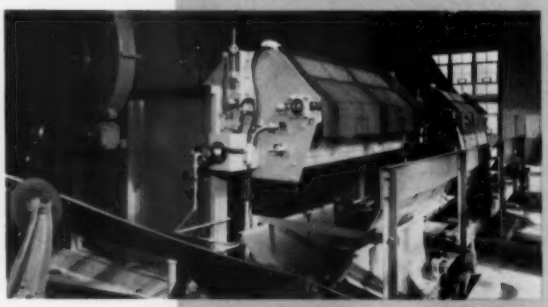
NON-CLOG DIFFUSERS

Applicable to any aeration requirement, Eimco-Process Non-Clog Diffusers provide even distribution of finely divided air bubbles with freedom from common clogging problems. Low head loss is inherent in the design and transfer efficiency remains at a consistently high level over long periods of operation. Available for standard pipe sizes from 1½″ to 4″, or tapped to replace existing diffusers, they can be furnished separately or assembled on headers. Non-Clog Diffusers are competitively priced and normally available from stock.



ROTOBELT VACUUM FILTERS

The Eimco Rotobelt Filter has been designed to remove the filter medium from the drum, discharge the cake, wash the medium front and back and return the medium to the drum every filter cycle. No air blow is needed . . . no filtrate blowback is possible. The Rotobelt can discharge filter cake as thin as 1/16″. Consistent high vacuum levels of 22″ Hg. or more across the face of the drum and positive sealing at the drum edge result in reduced consumption of chemical reagents. Rotobelt filters may be obtained in a full range of sizes from 18″ dia. x 12″ face to 14′ dia. x 14′ face.



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JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

UTILITIES INSPECTION & SERVICE RECORD

DESCRIPTION

LOCATION

MAINT. TO BE DONE BY:

ITEM NO.	WORK TO BE DONE BY	FREQUENCY	TIME

SERVICE RECORD

DATE	WORK DONE	SIGNED	DATE	WORK DONE	SIGNED	DATE	WORK DONE	SIGNED

FIG. 3—HEADINGS on maintenance, front of card above, back of card below.

sewers and make underground repairs. In this connection, the matter of safety in sewer maintenance and sewage treatment, too often neglected, is of prime importance to those participating in this type of operation.

Safety Measures

Extreme precautions should be taken during all sewer cleaning and maintenance operations to prevent possible accidents. The accident rate in the field of sewer maintenance and sewage treatment operation can probably be traced in a large percentage to human error, lack of training, and negligence. Hazards to which sewer maintenance personnel are exposed can be separated into five groups,[8] as follows:

1. Physical injuries from mechanical failures.
2. Disease or complications caused by infection fom contaminated materials.
3. Disabilities caused by gas inhalation.
4. Collapse due to oxygen deficiency.
5. Effects caused by radiation.

Almost all injuries resulting from mechanical failures may be traced to lack of precautionary safety measures. Dropped manhole and inlet castings, faulty manhole steps, wearing of improper footwear, inadequate barricades and hazard signals, as well as general carelessness, provide the usual causes of such accidents. Continued training in safety education and the practice of normal safety measures will reduce the frequency of this type of accident.

Infection can be reduced through the use of protective clothing and by practicing normal safety measures. Cognizance of the possible infection hazards which exist will aid in elimination of this type of accident. Some municipalties provide treated coveralls, safety hats, impervious gloves, and safety shoes or boots to their maintenance crews. Use of hot water and soap after exposure to possible contaminated areas will aid in the control of infection.

Presence of gas hazards in sewers may result from a number of causes,[9] as follows:

1. Leaks of natural sources, such as wells.
2. Leakage of gas, gasoline, or solvents from adjacent underground structures or utilities.
3. Discharge of volatile wastes into sewers from industrial sites.
4. Accidental discharge, or spillage, of explosive materials which might reach the sewer.
5. Formation of gas from septic sewage, resulting from complete or partial stoppages and sluggish flows.

Accidents resulting from gas can be avoided by strict application and enforcement of safety regulations and by use of available equipment and safety appliances. The slightest infractions of the rules pertaining to safe operation in the presence of gas may result in injury or death to personnel, extensive damage to equipment and property, and complete loss of utility services.

The following safety rules are pertinent to operations in hazardous gas areas and are of prime importance to sewer cleaning crews:

1. Smoking, lighted matches, or open flames are prohibited in the vicinity of open manholes.
2. Tests for toxic or explosive gases, as well as oxygen deficiency, will be made in manholes and sewers prior to the time personnel are permitted to enter.
3. Personnel shall, in no case, work alone in a confined area where there is a suspicion of free gas.
4. Manholes and sewers shall be ventilated by natural or mechanical means prior to entry of personnel.

Gas safety appliances that are available for use by sewer cleaning crews include gas masks, gas detectors, combustible gas indicators, safety lamps, air blowers, and first aid kits.

Perhaps the most difficult hazard to explain in the sewer cleaning operation is oxygen deficiency. Many workmen who are untrained assume that the wearing of a gas mask provides them with protection against all hazards. Even though a municipality cannot afford air blowers or respirators, sound practice dictates that adjacent manholes be opened for some time prior to entry of personnel. Acceptance of this precaution will permit some natural circulation of air.

The matter of radiation hazard is a specialized field and will not affect too many localities. It appears that the many possibilities for use of atomic energy in the future will result in general radiation waste problems. Radiation detectors are available.

There are no rules for determining the amount of safety equipment necessary for the safety of a sewer cleaning operation. Obviously, each municipality and operation will vary both as to financial ability to support an extensive program and as to the type of sewer system under study.

It should be emphasized that there are a number of "common-sense" safety practices and regulations which can be applied to personnel and which do not increase the budget of the department. Department heads should insist on strict adherence to the basic fundamentals of safety. Many municipalities are unaware of the actual dollars lost through the lack of an adequate safety program.

Actual monetary savings may be demonstrated by the savings made in workmen's compensation premiums of comparable cities with safety programs of varying intensity. Other savings may result from full-time employment of personnel without the necessity of hiring temporary manpower to replace accident losses. The intangible losses that cannot be directly ascertained are generally believed to exceed direct costs of accidents by about 500 per cent. At this rate, the financial loss developing from accidents and lack of safety programs could achieve a staggering total.

The importance of a continuing safety program should also be emphasized. New employees not only should be trained in the tasks they are to perform, but must be indoctrinated with the safety program prior to functioning in their positions. This is particularly true of employees used in the sewer maintenance and sewage treatment fields because of the attendant hazards.

Once the employee is started on his job, the safety program must not be relaxed. It appears that from 3 to 5 hours per month are spent on safety training for employees where an adequate program is in operation.[10] Strict adherence to penalties for violation of policies and directives should be followed.

Because of the serious hazards existing in sewer cleaning and maintenance work, and because of the fairly high frequency of accidents in this field, it is important that an adequate safety program be adopted in conjunction with the maintenance program.

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Industrial Wastes

in municipal sewage plants

by THEODORE JAFFE

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Many municipal plants have industrial wastes added after the plants have been built, and this situation can create difficulties. Depending upon the characteristics, volume, temperature, etc. of the waste, and the condition of the sewers and the receiving treatment plant, all sorts of operational troubles may arise.

Characteristics of Industrial Wastes

Industrial wastes may require special attention because they differ from domestic sewage. Among these differing characteristics may be:

1. Large volume per day, or extreme fluctuations in volume at various times of the day.
2. Excessive volumes at certain periods of the year; e.g. any seasonal plant operation such as the citrus concentrate industry.
3. High temperature.
4. High concentration of settleable solids.
5. Acid or alkaline.
6. Organic load (BOD) higher than domestic sewage.
7. Harmful substances in the wastes; e.g. metal salts such as lead, chromium, copper, etc.
8. Grease or oils.
9. Explosive or combustible materials, a possible hazard to sewers as well as interference with plant operation.
10. Odor forming substances or odors.
11. Deficiency in essential nutrients or overbalance with one type of microbial food; e.g. textile desizing wastes having an excess of starch but lacking in nitrogen and phosphorus.
12. Radioactive materials.

Although the above list is not complete, it can be seen that industrial wastes may cause difficulties from the point of entrance into the sewer, through the treatment plant, and into the receiving stream. These difficulties may include hazards to structures, equipment, processes, and personnel, or they may be merely bothersome. In any event, they may require special thinking and special attention.

Industrial Waste Surveys

Generally speaking each industrial waste presents a special, new problem. Every plant waste differs from any other waste even though the industry may be the same. Also, every sewer system, every treatment plant, and particularly every receiving stream is different from any other. Certainly all textile wastes, all pickling wastes, all dairy wastes, etc., have some common industry-wide characteristics; but any one textile mill's wastes will be different from another textile mill's wastes in many ways. Usually these differences are extremely important, and why industrial waste surveys are important.

A waste survey is essential for each new situation. The survey should determine in what manner and to what degree the particular waste is similar to others and also how it differs from any other. These differences and similarities should take into account all the other factors in the over-all specific situation.

For example: a new industry wishes to dispose of its liquid wastes through an existing collection system and municipal treatment plant. Analysis shows the waste to be very acid, with a pH of 2.0, but of relatively small volume.

Some of the over-all factors to be considered are:

1. Is the waste discharged in a "slug," all at once, or over a period of hours? If a slug, at what time of day? (It is easy to see that if the waste is discharged over 24 hours, or at a time of peak flow of sanitary sewage, the effect would be entirely different than if discharged during minimum flow in the sewer.)
2. What change in the pH of the raw sewage entering the treatment will result from this waste?
3. What type of treatment—primary or secondary, sludge digestion, etc.—is used at the municipal plant, and

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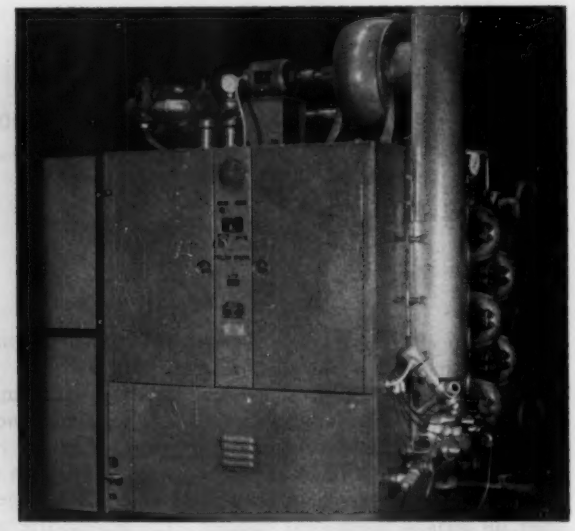

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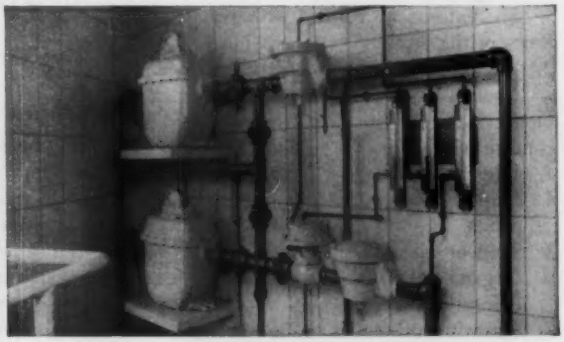

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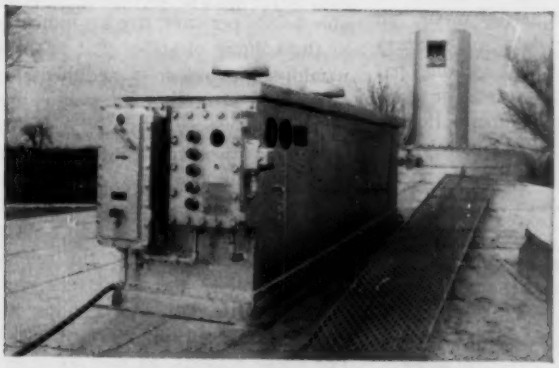

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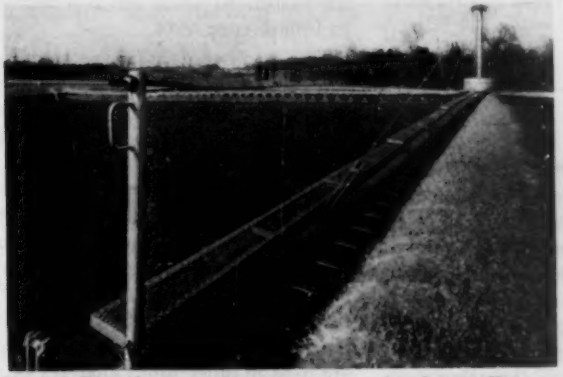

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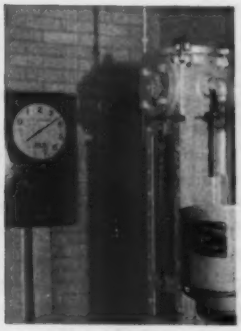

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will there be any effect on the units or the processes?

4. Could the waste be discharged directly into the receiving stream without treatment? This might be possible if there were sufficient dilution (flow) in the stream.
5. Is there another industry nearby producing an alkaline waste? (A combination of these two wastes in a simple holding or mixing tank might result in a liquid with a pH around 7.0 and require no further treatment.)

As a result of the waste survey, the decision can be made as to whether or not the industrial waste can be admitted to the sewer system and the treatment plant, or should it be excluded. Results of the survey will show that if the waste can be allowed into the municipal system, are there any restrictions or qualifications? For example, one waste might be admitted and handled if discharged over 24 hours; another might require separation of "clean," cooling waters to reduce the volume; still another might require neutralization for pH adjustment, and so on. In many communities sewer ordinances are in effect to regulate the discharge of industrial wastes. Some suggestions for these will be discussed later in these articles.

Why Industrial Wastes In Municipal Sewers

Why are industrial wastes accepted into the sewers, if they cause trouble? There are several reasons. First, industry pays taxes. As a tax-payer, industry is entitled to certain services from the community, e.g. drinking water, fire protection, etc. Waste disposal is a community service and should be furnished all tax-payers provided their wastes are not an unreasonable burden.

Secondly, in many instances both industry and the community benefit from a combined disposal system. Industry benefits in better control; possibly lower cost of treatment (by utilizing the nutrients in domestic sewage); no need for separate facilities; and others. The community benefits in more complete treatment facilities; lower unit costs; and the economic value of having the industry in their town instead of some other town.

It should be kept in mind that to the difficulties that industrial wastes may cause in existing treatment plants are different from the situation where a new plant is to be designed and built. Many industrial wastes will cause little or no troubles, if a treatment plant is designed with the advance knowledge that these wastes are to be treated with the domestic sewage at a single plant.

If trouble exists in a plant, how can one tell whether an industrial waste or something else, is the cause? Perhaps the first thing required is some idea of the characteristics of an average sanitary sewage in the town, so that it can be determined whether any industrial wastes are entering the sewers. By sanitary sewage is meant one that contains no industrial waste. In Table 1, are some data for sanitary sewages, based on 100 gallons per capita per day flow. (Note: The average per capita water consumption in the U. S. is now approximately 147 gal per day.)

Table 1

Sanitary Sewage Values

Item	Average[1]	Usual Range
Susp. Sol. (total)	254. mg/L	350-90 mg/L
Susp. Sol. (vol.)	171. mg/L	85-65% of above
Settleable Solids	5.4 ml/L	10-2 ml/L
5 day BOD	262. mg/L	350-80 mg/L
pH	7.3	8.0-6.0
Org. Nit.	22.1 mg/L	30-15 mg/L

[1]See Ref. No. 1

Laboratory Tests

Plant records are a valuable source of information in an investigation of this sort, and point out a need for the gathering and keeping of such records. A good operator should know the color, odor, physical appearance, etc. of the sewage entering the plant. Changes in any of these characteristics can be easily noticed and will show that something different has been run into the sewers. Many industrial wastes cannot be detected this readily and so some routine checking of the raw sewage should be done at all treatment plants.

What testing procedures should be performed in an average size sewage treatment plant? The tests discussed here do not require much expensive equipment, and both the tests and the equipment will be of value in daily, routine operation as well as for industrial wastes.

One of the simpler tests, yet one of value in industrial wastes studies, is pH. The best type of pH instrument for industrial wastes is the pH meter. Colorimetric pH testing often does not work with these wastes because the waste itself may be colored, or it may react with the pH indicators to give off-colors. The pH meter can be operated on batteries or plugged in, can be either for laboratory use or a portable type. It can be purchased from about $100 on up. These are rugged instruments, reliable, and do not require any special training to operate.

For the *settleable solids test* only an Imhoff cone and stand are required. These also are very inexpensive, costing about $15.00. The results of this test, expressed as milliliters of settleable solids per liter, are an indication of the volume of solids that probably would settle out in a sedimentation tank in the same time interval as used in the laboratory test. The Imhoff cone test measures only settleable solids and *not* suspended solids. Also, although this test gives approximately the volume of solids, but tells nothing of the concentration nor the relative composition of the solids, i.e. how much volatile (organic) solids and how much fixed (inorganic) solids. For these reasons, as well as others, the suspended solids test is preferable to Imhoff cone tests.

The *suspended solids* test requires some technique with an analytical balance. In addition to an analytical balance, Gooch crucibles, suction flasks and suction, a drying oven (103°C), and a desiccator are required. This costs about $450.00. If it is desired to determine how much of the suspended solids are organic and how much is mineral matter, then a muffle furnace is also needed. Incidentally, the drying oven and the muffle furnace are used in other solids analyses (e.g. sludge solids) as well as for other laboratory purposes.

For the 5 day, *B.O.D. test* (at 20°C) the major item of equipment is an incubator with a thermostat capable of holding the temperature constant. A reasonable sized incubator will cost from $500.00 on up. In addition to this, special B.O.D. bottles as well as a burette, flasks, and chemicals will be needed.

All of the above items of equipment should be available at any sewage treatment plant and all operators at any plant should be familiar with these tests as routine procedures. The actual steps of the tests are given in "Standard Methods"[2] (industrial

waste analyses are given in a separate section).

Nitrogen analyses are usually run in the larger laboratories, rather than as routine procedures. However, where any considerable amount of certain types of industrial wastes are involved, nitrogen analyses are of great value.

If industrial wastes are a problem, or suspected of causing trouble, the operator should make all the tests mentioned above, including both total and volatile suspended solids. The attempt should be made to obtain daily samples of the raw sewage for at least two weeks. If it is impossible to run daily samples, run as many as possible during one week, then change the days the next week, till each day of the week has been sampled at least twice.

These daily samples should be made by taking hourly samples and then composing a portion of each of these according to the flow at the time. The hourly samples should receive a pH check as soon as possible. If any of the test results vary greatly from the usual values for that particular raw sewage, the operator may suspect that an industrial waste has been run into the sewer system. Further, if the raw sewage entering the treatment plant does have a pH, or B.O.D., or solids content greatly different from the domestic sewage, it may require special attention or treatment.

On the basis of the simpler tests described above, what industries might be suspected when variations from the average are found? Table 2 lists characteristics of some industrial wastes and their effects.

Table 2
Effects of Industrial Wastes

Effect	Industries
pH—acid	Tanning; metal plating; some types of pulp and paper mills; some textile dry mills; chemical industry.
pH—alkaline	Beet sugar (Steffans process); beet sugar-lime drainage; tannery; textile; laundry; milk; some types of pulp and paper mills.
Solids—inorganic	Beet sugar; tannery; citrus; paper and pulp; laundry.
—organic	Sugar; milk and dairy; canning; some textile; meat packing and slaughter-house; fermentation.
BOD	All those under organic solids; pharmaceutical and biological plants; food processing.

Most discussions of industrial wastes refer to "population equivalents," a means of expressing the strength and volume of a waste in terms of people. It is often used to show the effect of a waste when figuring service charges, or the magnitude of a waste in relation to the town's population. A formula for calculating population equivalents is:

$$\text{P. E.} = \frac{\text{5 day BOD (mg/L)} \times 8.34 \times \text{mgd}}{0.17}$$

Only two values are required, the 5 day B.O.D., and the flow in million gallons per day. When those data are put into the formula, the answer gives the number of persons required to contribute a domestic sewage of equivalent strength. For example, suppose an industrial plant produces 340,000 gallons per day of a liquid waste having a 5 day B.O.D. of 2,000 mg/L. When these data are substituted in the formula this industrial waste is determined to be equivalent to the sanitary sewage from 33,360 persons.

Industrial wastes may affect the operation of any sewage treatment unit located anywhere from plant influent to plant effluent. They may pass through a plant and cause difficulties in the receiving stream by oxygen demands, sludge deposits, toxic materials, etc. They may cause trouble in the collection lines even before the waste enters a treatment plant.

Collection Systems

Since the collection sewers are the first portion of a disposal system, let's look at some situations that have arisen in the sewers due to industrial wastes. At Ballston Spa, N. Y. the municipal sewers receive wastes from various industries[3]. Among these industries is a hide and leather company discharging three tons of lime per day, along with other wastes, particularly hair. This combination tended to settle in the 30 inch interceptor as lime deposits and long, stringy masses of hair. To loosen these accumulations, an expanding type sewer cleaner is pulled through the sewer twice a year. The solids are allowed to continue down the system to the treatment plant (cleaning is done during high flows) and the material is removed at the grit chambers and wet wells. (See later section on grit removal.)

Prior to the adoption of a sound sewer ordinance in 1950, the Hartford, Conn. Sewage Plant had some difficulties with a metal pickling waste entering its collection system[4]. This was an acid waste (sulfuric acid), which under prior agreement could be discharged up to "480 cu ft of 1 per cent sulfuric acid over a 24 hour period if diluted down to 0.1 per cent and never more than 0.2 per cent"[3]. The waste, over a nine year period, disintegrated the Portland cement joints of 10 inch sewer tiles, attacked manhole bases and mortar joints, and deposited large amounts of iron scale. The solution to this problem lay in the new ordinance which set a lower pH limit, and an iron limit. It was further recommended that the industry install a grit chamber to remove the scale, and adjust the pH to comply with the new ordinance.

Incidentally, acid wastes may be discharged by any industries, using a pickling or cleaning step in their process; the acid manufacturing industry, chemical plants making or using organic acids and many other miscellaneous chemicals. While this is not a complete listing of possible sources of acid wastes, it should indicate the types of industries that might discharge an acid waste to a sewer system.

To summarize, the collection system difficulties that may be caused or increased by industrial waste discharges are: a) clogging; b) deterioration; c) explosion or fire hazard; d) coating of the sewer interiors; e) odors; f) interaction of one waste with another to cause any of the above conditions.

Screens and Grit Devices

Industrial wastes may increase the

volume of screenings and grit to be removed. They may interfere with the operation of these devices (and comminutors) by clogging or jamming them. Some types of industries that may discharge this type of waste are: vegetable canning, chicken processing; hog slaughterhouses; tanning; fish and shellfish canneries; resins and plastics; etc.

The situation at Ballston Spa, N. Y. mentioned above[3] regarding a tanning industry caused large amounts of grit to reach the treatment plant. Here, under normal operation 4 cu ft per day of solids are removed from the grit chamber. During the cleaning of the interceptor, 20 cu ft per day are removed. Most of the grit removed will consist of sand, lime deposits, and masses of hair and rag materials. These difficulties carried through into the sedimentation and digestion tank.

At the Niagara Falls, N. Y. plant[5], organic chemicals (resins and plastics) were discharged into the sewers. Among other troubles, these interfered with the screening operation. The plant had fine disc screens with 1/32 inch openings. These resinous materials would clog the screens. It was then necessary to take the unit out of service and remove the material by scraping and steam. How this situation was remedied was not stated in the article referred to.

Often, plant operators have temporary troubles, such as happened at Celina, Ohio[6]. A tomato cannery, connected to the municipal sewers, had screening units at the cannery. On one occasion however, these broke down and the sewage plant received the unscreened wastes in such quantities that the comminutor broke down. The rotten pulp and tomatoes piled up against the bar screen and had to be removed manually.

Sedimentation

Most any industrial waste having large amounts of settleable or suspended solids may cause an overloading of the sedimentation facilities at a treatment plant. Greases and oils will also cause trouble in these units. Large, sudden, fluctuations in flow may cause hydraulic overloads in primary tanks. This too, is bad for operation since these tanks can only remove solids effectively if sufficient detention time can be achieved. A large increase in volume of flow may shorten the detention time to such an extent that solids removal may drop close to zero. Often, these large, hydraulic shock loads are composed of relatively clean waters, e.g. cooling waters, and could be discharged to storm sewers or the receiving stream without any treatment. Plant operators experiencing large flow fluctuations might well investigate this possibility of direct discharge.

Secondary Treatment

Filters, activated sludge, and sludge digestion, all employ microorganisms to remove pollutional materials from liquid wastes. Since this removal is a biochemical action brought about by living creatures, the environment and food must be acceptable to them, and non-toxic. Moreover, the quantities and rates of feeding must be to the organisms' liking. It is up to the plant operator to control these factors in so far as he is able.

Many industrial wastes however, create such extremely adverse conditions that the operator cannot keep control and then the treatment process ceases to work. This is not a fault of the operator necessarily, but rather a characteristic of his workers—the microbes. The solution to the problem usually lies in adaptation of the microorganisms to the waste, better control at the plant, or possibly the exclusion of the waste from a secondary treatment plant. Many of these undesirable wastes might possibly be better handled by chemical precipitation and sludge filtration, or some other means.

The literature contains many references to problems of this sort. One plant in Fremont, Ohio[7] mentions that frequent slugs of acid wastes have stripped the filters of zoogleal growths, thus rendering the filters ineffective. At this same plant, on another occasion, large amounts of oil were received. Some of this passed onto the filters, producing clogging and ponding. The oil had to be removed before operation could be resumed.

Plating waste discharges are thought to have caused ponding and sloughing of the media from filters at the Marion and St. Mary's sewage treatment plants in Ohio[8]. At these plants the filter slimes were removed from the beds, at different depths. Upon examination for copper, chromium, and cyanide it was found that these had accumulated in the zoogleal slimes and were apparently affecting treatment efficiencies. At another Ohio plant, using the activated sludge process, this retention and accumulation was noted in the activated sludge. Apparently the microorganisms employed for sewage treatment tend to gather in metals and by so doing, retain enough to harm or even kill themselves. The organisms will not only retain the metals mentioned above, but will also retain nickel, copper, zinc, and others.

Another type of difficulty experienced in some plants is the increased organic loading on secondary treatment units caused by certain industrial wastes, such as organic chemicals, packing and slaughter houses, fermentation industries, some foods, and others. Most of these produce wastes in solution or colloidal solutions. With this type of waste very little removal or reduction is obtained by primary sedimentation. This means that we cannot count on having the usual 25 to 35 per cent removal of B.O.D., because the load in these wastes is soluble, not suspended. Failure to take this into account leads to serious overloading of the secondary treatment units. These wastes can be even more of a problem if they are received in fluctuating flows.

Activated sludge plants receiving packing house wastes may have had difficulties with sludge rising in their secondary settling tanks. This may be due to increased nitrification of the organic material in these wastes. It has been suggested[9] that rapid removal of the secondary sludge will relieve the situation, but will not cure it.

Digestion

Since sludge digestion is a biological process, it too may be adversely affected by some industrial wastes as are secondary treatment processes. Certain industrial wastes, particularly toxic metals, will inhibit or even stop the digestion process; other wastes may be beneficial.

Two instances of increased gas production in digesters might be mentioned here. Both of the plants received milk product wastes and both of them experienced an increase in the gas produced. The Celina, Ohio plant discussed above[6] received

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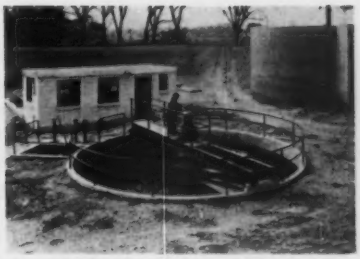

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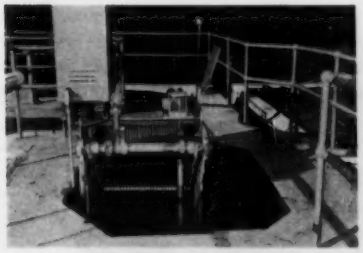

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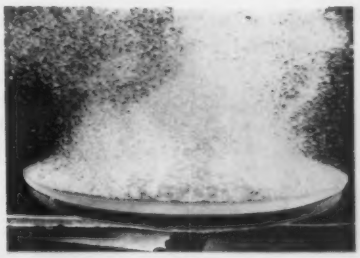

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as much as 25,000 lb of skim milk per day. When the milk had entered the digesters, gas production rose immediately, and within a short time, doubled in volume. The quality of the gas was not effected.

Another similar instance, this being whey, was reported from Marion, Ind.[10] Here, the increased load on the digesters was 18 per cent of the total load, and gas production increased. The same plant, on another occasion, handled 11,000 gal of condensed milk by bringing it directly into the digesters rather than through the plant. This was done so that the activated sludge process would not be upset by this huge, organic overload.

Digestion operation does not always benefit from industrial wastes, however. One example is that of the Ley Creek Plant, at Syracuse, N. Y.[11] Here penicillin manufacturing wastes were discharged to this activated sludge plant. It soon was noticed that the secondary sludge was much lighter than that from domestic sewage. This imposed a burden on the digesters because of a large volumetric load, even though the organic solids load might remain the same.

Another type of difficulty is that reported from Monroe, Mich.[12], with the wastes from paper mills. In this case, because of heavy concentrations of the sludge, the pumps from the clarifiers to the digesters would clog. In the digesters themselves, heating of the sludge became a problem because large volumes had to be pumped. Further, the digesting sludge tended to separate into three layers, a heavy fibrous-like material on top, a supernatant layer in the middle, and a heavy sludge at the bottom. The sludge could not be mixed and would even break the heating coils because of its compactness.

Miscellaneous

The use of chlorine, either pre or post chlorination, can be greatly influenced by industrial wastes. In some instances, plants receive chlorine or similar oxidizing materials in their influent. The Niagara Falls plant mentioned previously[5] has received as much as 300 to 800 mg/l of free chlorine in its influent due to industrial wastes. On the other hand, the same plant often found that the chlorine demand of the influent might go to 100 to 200 mg/l due to chlorine reacting compounds from chemical industries.

Another example of high chlorine demands has been reported at the New Haven, Conn. plant[13], and is attributed to a textile dyeing plant. By measures taken at the dyeing plant, the problem was brought under control.

One point needing attention is the possibility of some of these wastes interfering with laboratory tests, particularly the B. O. D. test. If the wastes contain chlorine, toxic metals, reducing substances, and other materials, the B. O. D. test may give results that are grossly incorrect. Plant operators and chemists must constantly be alert to these possibilities in running the tests and in interpreting the test results.

Industrial wastes very frequently cause odor problems. These odors may arise in the collection system, the treatment plant, or both. Some odors may be unpleasant, while others may be harmful, and still others may be dangerous. The odor problem has been discussed in a previous article of this series[14], and so only one rather unusual problem will be mentioned here.

At the Suffern, N. Y. treatment plant[15] complaints about odors were received. However, the complaint was that the odors were "like perfume" rather than like sewage. It was found that these odors, (not affecting operation), were due to a cosmetic manufacturing plant. The offending—but not offensive?—portion of the waste was segregated at the manufacturing plant site, treated, and discharged into the river.

While many other situations could be described where industrial wastes affected plant operation adversely, these examples should indicate the types of difficulties and some of the wastes responsible. It should be remembered however, that several industrial wastes might be combined to produce a less troublesome waste, e.g. an acid waste from one manufacturer might be mixed with an alkaline waste from another plant resulting in a neutral combined waste. Sometimes we can combine wastes to precipitate objectionable materials, or to neutralize offensive odors. This combining of wastes must be carefully done for it is possible that the resultant waste might be more objectionable than any of the original ones.

If industrial wastes cause such problems, the question arises: "Why admit these industrial wastes into a municipal collection and treatment system?" The answer to this question was discussed previously in this article and will not be repeated here. However, illustrations of how industrial wastes and municipal sewage can be treated together without difficulties can be found in the literature. One of these is the South San Francisco plant[16] handling packing-house, tannery, laundry, and pickling wastes, along with domestic sewage.

The matter of combined treatment is more of a designer's problem than an operator's; for these schemes to work well, a treatment plant must be designed to accommodate and treat industrial wastes. If the industrial wastes are tapped into an existing system, it is very likely that difficulties may arise. In this connection it is interesting to note the results of a survey[17] of 200 sewage treatment plants handling domestic sewage and industrial wastes as recorded in Table 3.

Table 3
Industrial Waste Problems at Municipal Plants

Problem	Plants Replying (%)
No problems	39
Flow tolerated at reduced efficiency	20
Flow can be handled by special operating techniques	14
Flow can be handled by installation of proper equipment	29
Problem cannot be solved at treatment plant	17

The import of the above figures lies in the fact that only 39 percent of these plants did not have problems or a loss in efficiency associated with the industrial wastes. Further, 17 per cent of the plants felt that no possible change in operation nor special equipment would enable them to successfully treat the wastes. These are rather remarkable statistics!

Sewer Ordinances

No discussion of industrial waste treatment at municipal plants would be complete without mentioning sewer ordinances. By means of an ordinance, industrial waste discharges may be controlled. Some wastes—toxic, hazardous, etc.—might be com-

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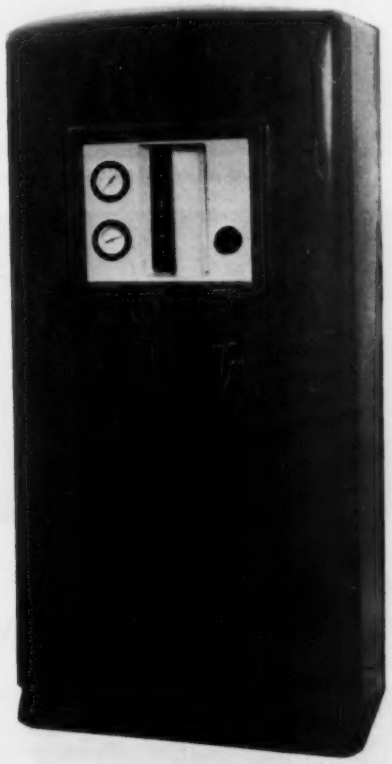
DISINFECTION OF SEWAGE

The need for sewage disinfection cannot be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



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ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

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Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

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pletely excluded from the system. Others will have limits set on them such as pH limits; lb of B. O. D. per day; lb of chlorine demand per day; etc. Still others may be admitted into the system only after preliminary treatment at the industrial site, e.g. the screening of feathers from poultry processing wastes; the removal of hair from hide and leather wastes, etc. Some wastes may be segregated with certain portions held and discharged over a period of time instead of in concentrated slugs.

Another advantage of a sewer ordinance is to set up an equitable basis for treatment charges. Industry should pay a portion of the cost of treating their wastes at a municipal plant. Many formulae have been used so as to make the charges fair to industry and the individual. Since the plant operator is not concerned with formulating charges, this subject will not be discussed. However, since he may be asked for advice on sewer ordinances we would recommend as a beginning, that he become familiar with the "Manual of Practice" No. 3 of the F.S.I.W.A.[17]. Although this was published in 1949, it is still a good model from which to work. To get the feeling of ordinances and their need, an operator might read the "Industrial Waste Forum"[19] and an article by Eldridge on industrial wastes[20].

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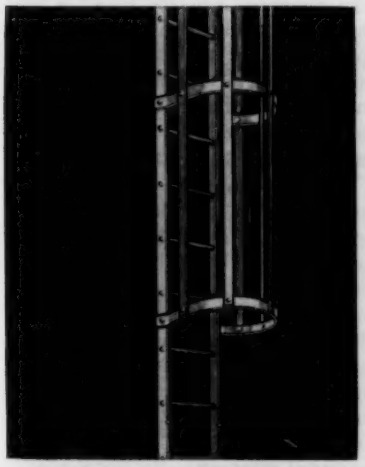

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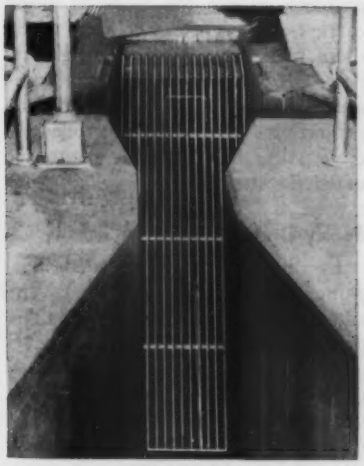

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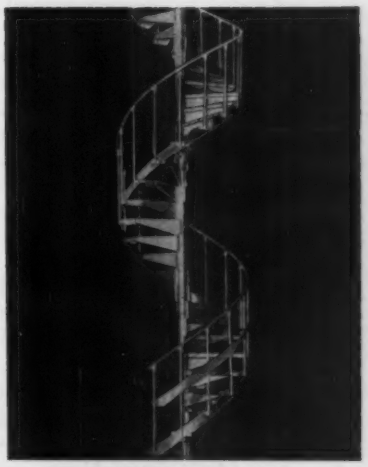

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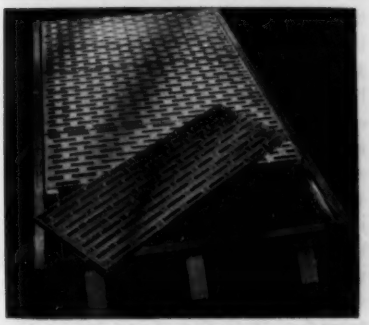

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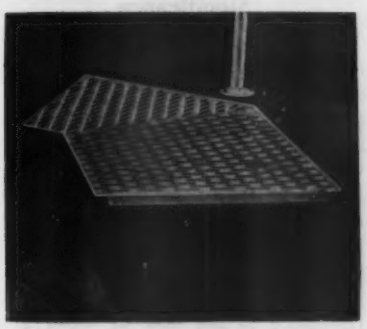

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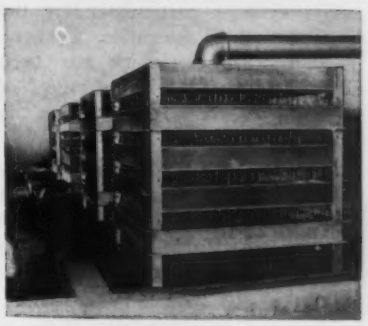

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Drainage During Construction

by LEO J. RITTER, JR.
Construction Editor, Water and Sewage Works

The importance of adequate drainage during construction operations can not be overemphasized. Adequate drainage—provided in advance of immediate needs—will often make a successful contract operation possible in areas of high water table, under difficult soil conditions, or in time of inclement weather. Without adequate drainage, a contractor frequently finds himself in serious difficulties when inclement weather strikes, with wheeled equipment bogged down, work on foundations and drainage structures stopped because of high water, mounting costs, and so on.

A definitive treatment of the subject of construction drainage is understandably difficult—primarily because solutions to drainage problems are improvised on the spot, as the situation develops. Obviously, this type of information rarely appears in published literature. Nevertheless, it is important to understand basic drainage concepts, particularly as they relate to soil conditions at the construction site.

Drainage Characteristics of Soils

Information is available concerning drainage characteristics of the soil groups delineated in the classification systems particularly for the Unified Soil Classification System. This information, which has been adapted from TM5-541, *Control of Soils in Military Construction,* is presented in Table 1.

In order to permit interpretation of this information in terms of the other two commonly used classifications systems, Table 2 gives the relationships among the three major systems.

Well-Draining Soils

Clean sands and gravel—such as in the GW, GP, SW, and SP groups—fall into this category. These soils may be drained readily by gravity systems. On highway construction, open ditches may frequently be used in these soils to intercept and carry away water which comes in from surrounding areas. Control of ground water in such soils is normally not a problem, unless the work is being carried on in very flat country where there is no ready outlet for gravity flow. If the ground water table around the site of a construction project is effectively controlled in these soils, then it will be controlled under the site, also.

Poorly Draining Soils

In this group are included inorganic and organic fine sands and silts, and organic clays of low compressibility, together with the coarse-grained soils which contain an excess of non-plastic fines. Soils in the ML, OL, MH, GM, and SM groups, and many of the Pt group would generally fall into this category. Drainage by gravity alone is usually quite difficult for these soils.

Impervious Soils

Fine-grained, homogeneous, plastic soils and coarse-grained soils which contain plastic fines belong in this group. This would usually include the GC, SC, CL, CH, and OH groups. Any drainage process is apt to be difficult and expensive in these soils.

Permeability—Its Practical Significance

A term widely used by soil engineers to describe the drainage characteristics of soil is *permeability.* By permeability is meant the property of a soil which permits water to flow through it. Relatively coarse soils, like clean sands and gravels, which offer relatively little resistance to the flow of water are said to be *permeable* or *pervious* soils. Fine-grained soils, particularly clays, which offer great resistance to the flow of water are said to be *relatively impervious* or *impermeable.* Some water does move through these soils, however.

Soil engineers—particularly those who are concerned with dams or other water-retaining structures—use a more definite measure of permeability, called the *coefficient of permeability, k.* The coefficient of permeability may be determined in the laboratory by tests upon an undisturbed sample of soil. It is defined as the discharge velocity under a unit hydraulic gradient. Neither the test procedure nor the exact value of k are of specific significance to the highway or bridge contractor. Values of k do have general significance, when related to experience.

Column (6) of Table 1 gives typical ranges of values for the coefficient of permeability for the soil groups of the Unified Soil Classification System. Units used are centimeters per second. For example, 10^{-2} cm per sec means 0.01 cm per sec. Again the contractor is seldom interested in precise values of k; his only interest is in the range of values of the different soil types and their practical meaning.

Peck, Hanson, and Thornburn, in their book *Foundation Engineering* (John Wiley & Sons, 1953) give practical significance to the coefficient of premeability, as follows.

"When the depth of excavation is greater than the distance to the free water service in a pervious soil having a coefficient of permeability greater than about 10^{-3} cm/sec the soil must be drained to permit construction of foundations in the dry. If the coefficient of permeability of the soil is within the range of 10^{-3} to 10^{-5} cm/sec, the quantity of water that seeps into the excavation may be inconsequential but drainage may still be required to maintain the stability of the sides and bottom of the excavation. If the coefficient of permeability is smaller than about 10^{-7} cm/sec the soil is likely to possess sufficient cohesion to overcome the influence of the seepage forces, and drainage may not be required, even if the excavation extends for a considerable depth below the water table."

Of course, the above discussion applies to ground water. Drainage will still have to be provided to take care of surface water and precipitation, irrespective of soil type.

Structural Excavations

The method of drainage chosen either for intercepting water or re-

Table I.

Drainage Characteristics of Soil

Major Divisions (1)	(2)	Letter (3)	Name (4)	Drainage Characteristics (5)	Permeability Cm Per Sec (6)
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	$>10^{-2}$
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines	Excellent	$>10^{-2}$
		GM d	Silty gravels, gravel-sand-silt mixtures	Fair to poor	10^{-3} to 10^{-6}
		GM u		Poor to practically impervious	
		GC	Clayey gravels, gravel-sand-clay mixtures	Poor to practically impervious	10^{-6} to 10^{-8}
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines	Excellent	$>10^{-3}$
		SP	Poorly graded sands or gravelly sands, little or no fines	Excellent	$>10^{-3}$
		SM d	Silty sands, sand-silt mixtures	Fair to Poor	10^{-3} to 10^{-6}
		SM u		Poor to practically impervious	
		SC	Clayey sands, sand-clay mixtures	Poor to practically impervious	10^{-6} to 10^{-8}
FINE GRAINED SOILS	SILTS AND CLAYS LL<50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Fair to Poor	10^{-3} to 10^{-6}
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Practically impervious	10^{-6} to 10^{-8}
		OL	Organic silts and organic silt-clays of low plasticity	Poor	10^{-4} to 10^{-6}
	SILTS AND CLAYS LL>50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Fair to Poor	10^{-4} to 10^{-6}
		CH	Inorganic clays of high plasticity, fat clays	Practically impervious	10^{-6} to 10^{-8}
		OH	Organic clays of medium to high plasticity, organic silts	Practically impervious	10^{-6} to 10^{-8}
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils	Fair to Poor	Variable

moving it directly from an area of structural excavation depends upon the type of soil, the rate at which water must be removed, the cost of installation, and the length of time the drainage system must remain operative. For temporary construction drainage, low cost of installation is a primary consideration. Drainage of construction sites may be accomplished by the use of open ditches and sumps, closed drains, well points, deep well pumps, or one of a number of more elaborate and costly schemes which are not covered here.

Open Ditches and Sumps

Occasionally, it will be possible to drain a shallow structural excavation in a coarse-grained soil by means of gravity flow in open ditches. The necessity for using very flat side slopes along the sides of the excavation (because of seepage through the banks) and for finding a suitable outlet for the water precludes use of this method on most excavations.

However, common use is made of ditches in the bottom of the excavation to collect the water which seeps into the area. The ditches channel the water into one or more open sumps. A *sump* is a shallow pit into which water flows by gravity. The water is then pumped out and discharged away from the excavation. Regular gasoline-engine contractor pumps are normally used in combination with flexible hose. Selection of the proper size and type of pump to be used is based upon experience, estimates of the quantity of the water to be removed, and manufacturer's recommendations. Reliable pump manufacturers are willing and able to make definite recommendations to fit a particular situation.

If loose, fine or silty sands, or some silts, are involved, there is a definite possibility that boils and pumping may begin in the sump. This must be watched carefully while pumping is being carried on. It may be necessary to line the sides and bottom of the sump with a suitable filter material in order to prevent sand and silt from being washed away and pumped out with the water. Clean coarse sand and gravel make an excellent filter material.

Closed Drains

When the effect of seepage on open ditches and sumps is a problem, perforated pipe or open-jointed drain tile can be laid in trenches and backfilled with pervious filter material. For most soils, sand with a grading

Table 2.

Approximate Relationships Among the Major Soil Classification Systems

Unified System	AASHO	Civil Aeronautics Administration
GW	A-1-a	Gravely soils not included directly. Note upgrading permitted in table 1.
GP	A-1-a	
GM	A-1-a, A-2-4 or 5	
GC	A-2-6 or 7	
SW	A-1-b	
SP	A-3	E-1, 2 or 3
SM	A-1-b, A-2-4 or 5	E-4 or 5 (usually SM or SC)
SC	A-2-6 or 7	
ML	A-4	E-6
CL	A-6, A-7-5	
OL	A-4, A-7-5	E-6
MH	A-5	E-10, 11 or 12
CH	A-7	E-8 (usually L group)
OH	A-7	E-9 (usually not CH)
Pt		E-13

comparable to that of ordinary concrete sand makes a suitable filter. Where perforated pipe is used, the width of the openings in the drain pipe should preferably be equal to about the 60 percent size (D_{60}) of the surrounding material.

Well Points

On large jobs which involve excavation to a considerable depth below the water table in pervious soils, well points are frequently used to lower the water table below the bottom of the excavation. A *well point* is a perforated metal pipe which is generally about 3 feet in length and from 1½ to 2½ inches O.D. The well point is attached to the bottom of a riser pipe of similar size and is jetted into position. The end of the pipe below the surface is protected by a suitable granular filter. At the top, a line of well points is connected at intervals of from 2 to 6 feet in a straight line to a header pipe, which in turn is connected to a suction pump.

The water table cannot be lowered more than about 15 feet by a single installation of well points, because of the limitations on suction pumps. Further lowering of the water table for deep excavations can be accomplished by using several lines at successively lower elevations, so that the level of the water is lowered in stages.

Well points are not effective in soils which have an effective size less than about 0.05 mm, or a coefficient of permeability less than about 10^{-4} cm/sec, unless gravity is supplemented by vacuum applied to the well points, in which case finer soils may be drained, although drainage usually requires a long time. Clays and other relatively impervious soils can not be drained by well points because of their low permeabilities.

The design and installation of well point systems is a specialized operation beyond the scope of this article and beyond the resources of the usual contracting organization. Such work is best done by specialized organizations who design the system, furnish the equipment, install it, and make sure it performs successfully.

Deep Well Pumps

The multi-stage well point system has disadvantages for very deep excavations, in that the water level is pulled down rather sharply at the sides of the excavation. Resulting high seepage pressures may lead to instability of the banks of the excavation. In such cases, and on large projects, use made be made of deep wells.

Such wells are cased holes ranging in diameter from 6 to 24 inches. The casing is perforated in the pervious zones. High-capacity and high-head pumps are installed, and usually powered by electric motors

Drainage of Working Area

Control of surface water is a basic requirement on practically all projects, particularly during the early phases of the work and during fil. construction.

To eliminate water which would interfere with construction operations at the site, excavate diversion ditches to concentrate all surface water into natural channels Dig outfall ditches to drain low or swampy spots. This work may be done at the same time as clearing and grubbing. Also give careful consideration to the drainage of pioneer roads, equipment areas, borrow pits and waste areas, if applicable.

Make maximum use of existing ditches and drainage features. In order to utilize natural drainage to the fullest possible extent, grading operations should be carried out downhill whenever possible. Schedule backfilling of existing ditches and drainage channels so as to permit the longest possible use of these facilities for temporary drainage.

Coordinate construction drainage plans with the layout and design of final drainage facilities to insure maximum use of temporary drains in building permanent facilities.

Avoiding Wet Weather Delays

In order to avoid wet weather delays in earthwork operations, use the following procedures.

Keep all work areas well graded and drained. If necessary, use every spare minute of a machine operator's time on temporary drainage facilities during early and critical stages of the work.

If work is to be discontinued on an area for even a short period of time, make a particular effort to remove ruts, depressions, and ridges by backblading and rolling with a steel-wheel or pneumatic tired roller to give a tight surface which will shed water. A drag is a good expedient, since it levels ruts and leaves no tracks behind it to fill with water.

In periods of wet weather, limit movement of material to sand and gravel, where possible. Avoid the movement of silt and clay. If there is a natural cover of more or less impervious material, cut open only the area which is necessary for efficient operation, since undisturbed ground can withstand heavy rains better than opened ground can, particularly in heavily sodded areas.

If possible, plan work so that operations can be shifted to other portions of the job, should one area become too wet to work properly.

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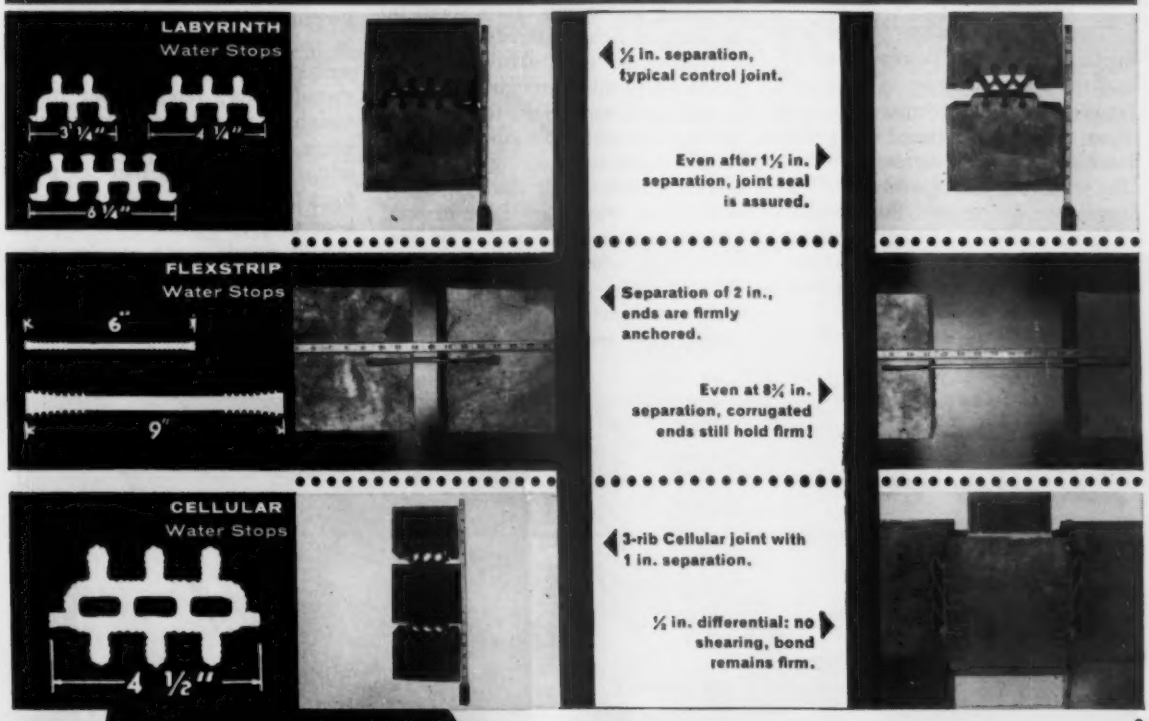

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Why Use Small Crane Shovels?

Close on the heels of the giant prime movers, the small shovel-crane steps into the construction scene, usually remaining until the last of the hundred miscellaneous lifting-excavating jobs has been completed.

In today's race with time and soaring costs, few construction sites are adequately equipped without at least one small, all-purpose crane on the job. Speeding from assignment to assignment, these versatile lightweights add flexibility and mobile muscle to equipment line-ups, whether it be on an earthmoving, pipeline, or a structure job.

Mobility, Versatility Key Factors

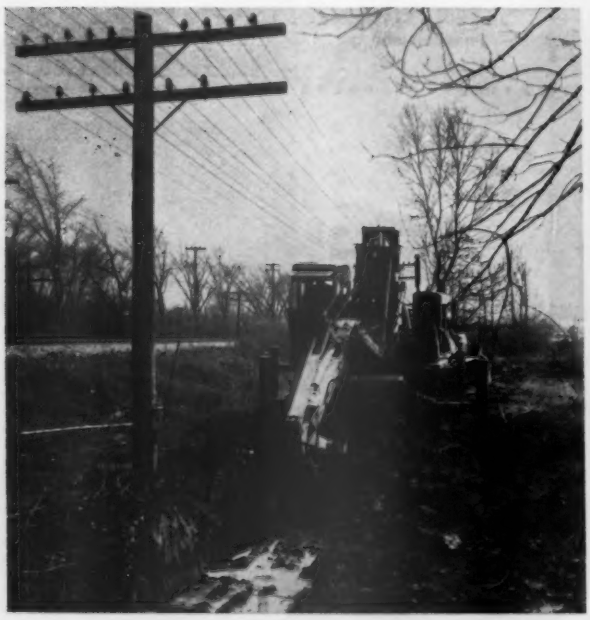
Two principal reasons for the wide application of small power cranes (5- to 8-ton lifting capacity, ⅜ cubic yard bucket) in modern construction are: First, the mobility offered in the small machine allows a contractor to handle scattered jobs quickly and economically; and second, the versatility to handle a wide assortment of assignments—both lifting and excavating—due to the interchangeability of front-end attachments.

Most power cranes work with ten or eleven different attachments: crane, back hoe, clam-shell, shovel, pile driver, backfiller, dragline, concrete bucket, grapple and magnet. This wide work range means increased output per equipment dollar and makes particularly attractive the initial low cost of the small machine—from $9,000 to $19,000 depending upon the type of mounting and the attachments desired.

A raft of other reasons contribute to the growing popularity of small crane equipment. Operators are comparatively easy to find and/or train . . . the little rig can work in tight quarters or in weight restricted areas where its big brothers can't . . . faster operating and swing cycles speed up handling of light materials as well as trenching and small excavations . . . increased profits through the mechanization of many jobs formerly requiring a considerable amount of expensive hand labor . . . ground conditions seldom impair work efficiency since small cranes are light in total weight and usually mounted on six-by-six (all wheel drive) crane carriers. Crawler-mounted models can wade through any muck or over rough, rocky terrain. They are usually within the eight-foot width limit for easy transporting over highways . . . To suit virtually every job need, the small rig can be mounted on crane carriers, crawler, or self-propelled (wagon) mounting, or even small trucks, pedestals, barges and rail cars. More and more contractors are discovering that the great majority of their lifts are well under the seven or eight ton capacity of the ⅜-yard class machine. The quick maneuverability of a small rig can save countless man-hours on many types of applications.

Economical Operation

Not to be forgotten, is the low operational and maintenance cost of keeping a crane working. As a case in point, Schield Bantam Company, well-known ⅜-yard shovel-crane manufacturer, reports that owner's maintenance and repair expenses average under $100.00 per year. Operating gas runs less than 14 gallons for a full work day. Downtime can be kept to a minimum since the lightweight repair parts can be rapidly shipped across the country, with the contractor frequently making minor repairs right on the job site.



Bucyrus-Erie Co.

MOBILITY-VERSATILITY allows contractor to handle scattered jobs quickly and economically.

Loads on Ditch Conduits

by L. E. LIVINGSTON, JR.
sales engineer of L. E. Livingston & Son, Dallas, Texas.

The accompanying chart provides a method for finding the necessary type of embedment for clay or concrete pipe in trenches, depending on type and density of soil, depth and width of trench, pipe size and safety factor. The solution to a problem is indicated in the key in Fig. 1. Starting at the lower left corner, a line (1) is drawn through Depth of Backfill and Trench Width (lower scale) to Depth/Width, and extended vertically (2) to a point on the curve corresponding to the type of backfill used. By extending this point horizontally to the right (3), Coefficient C_d is found. A line (4) through Density of Fill and Trench Width (upper scale) locates a point on pivot line A, and a line through this point and the previously determined Coefficient C_d yields Load on Pipe. A line (6) through Safety Factor and Pipe Size locates a point on pivot line B, and a line (7) through this point and Load on Pipe determines the required Embedment. Alternatively, the pivot point (B) is located by a line (7) through Load on Pipe and Embedment, and a line (6) through this point and Pipe Size gives the Safety Factor for the assumed conditions.

That portion of the chart which determines Load on Pipe is based on Marston's ditch loading formula:

$$W_c = C_d w B_d^2,$$

where W_c = load on pipe in lb/lin ft
C_d = a coefficient
w = density of fill in lb/cu ft
B_d = width of trench at top of pipe in ft

Pipe Sizes

Three Pipe Size scales are shown, with the corresponding ASTM specification number: C76-52 for standard strength reinforced concrete culvert pipe, C200-50T for extra strength clay sewer pipe, and C14-52 for concrete sewer pipe to 24-in. The C14-52 scale is extended to 36-in. based on ASTM C13-50T (standard strength clay sewer pipe). For simplicity, standard strength clay pipe sizes below 24-in. are omitted. These sizes generally will meet the C14-52 specifications, which are only slightly higher. The C76-52 scale is based on the load necessary to produce a 0.01-in. crack, and all scales are based on three-edge bearing strength.

Types of Embedment

The four types of embedment used in the chart are as shown in Fig. 2. Nomenclature and load factors are as given in the Concrete Pipe Handbook (American Concrete Pipe Association, 1951). A Load Factor scale is included to facilitate calculations involving other types of embedment, as for example, pipe encased in concrete, where the load factor may be taken as 2.8 plus encasement.

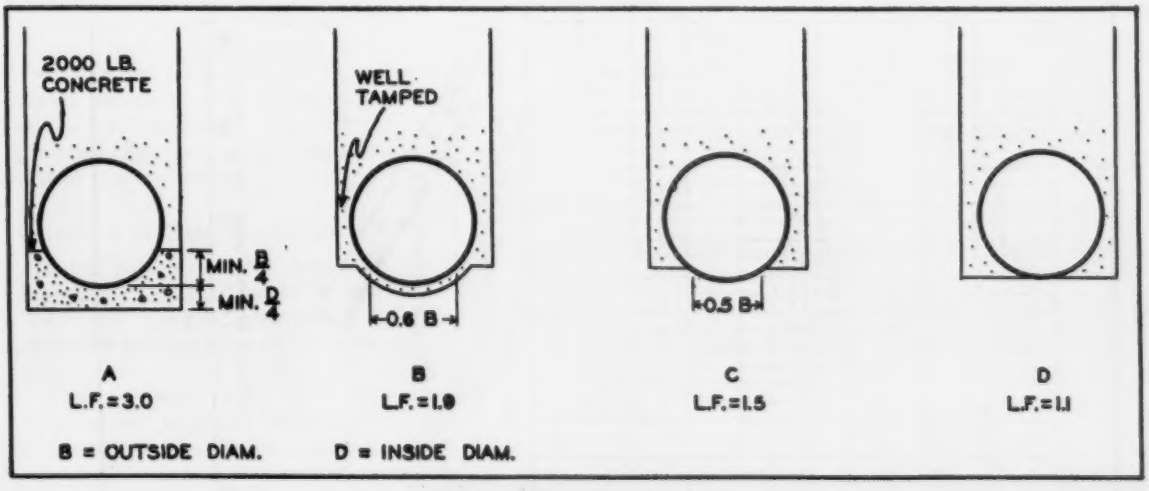


Fig. 2.—FOUR types of embedments.

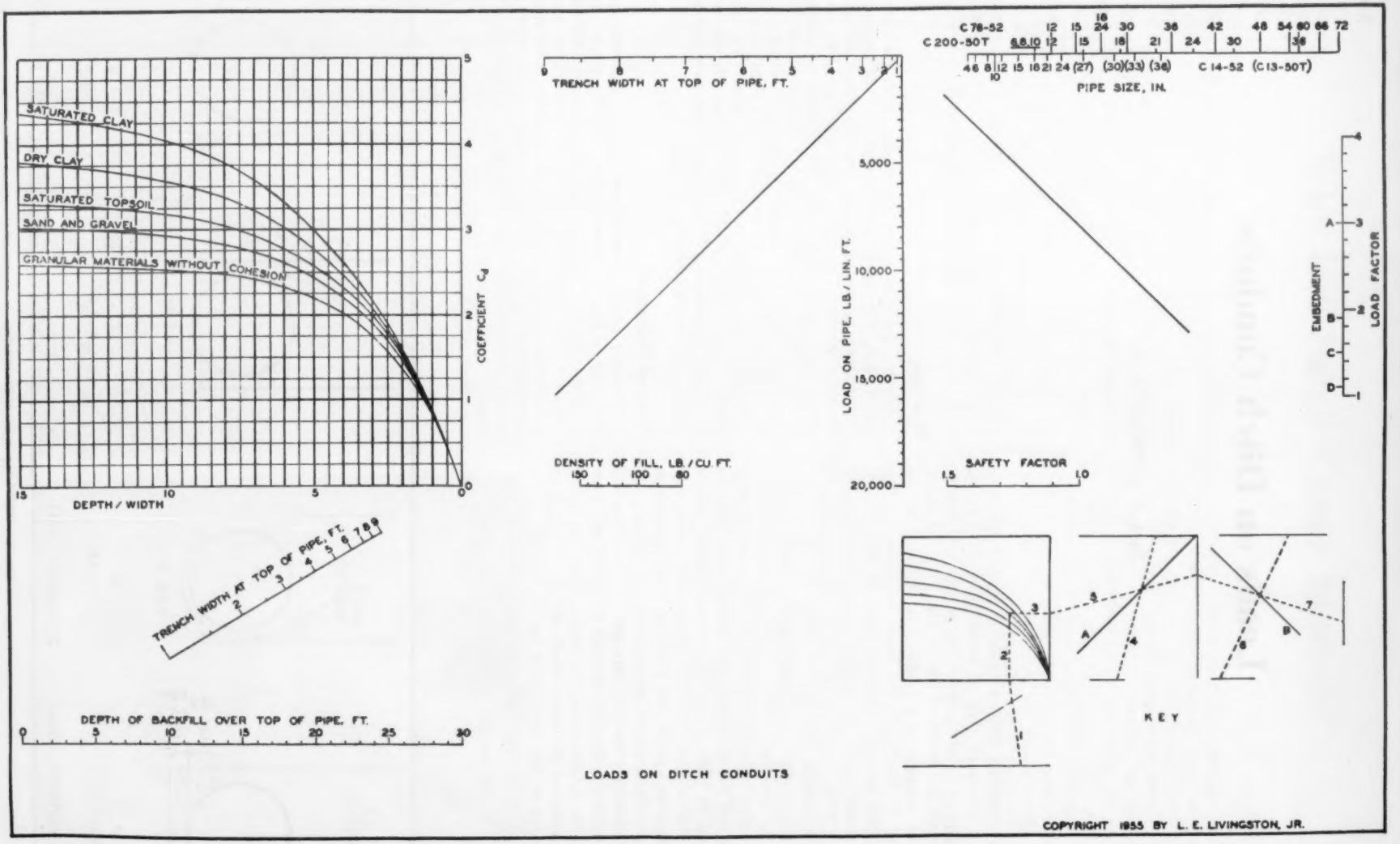


Fig. 1—ALIGNMENT chart for loads on ditch conduits.

Construction of Sewers

by L. K. CRAWFORD

Partner, Crawford, Murphy, Tilly, Consulting Engineers, Springfield, Ill.

It is not possible to condense into a few short pages all of the material that has been written on the design and construction of sewers. Therefore, it is necessary to limit this discussion on sewer construction, rather than hoping to cover the entire field.

For purposes of this discussion it is assumed that the sewage works operator might be called upon to build, supervise, or inspect the construction of sewer jobs. It is also assumed that the city officials depend on him to see to it that the local plumbers do a first-class job of making connections and building service sewers.

It is also assumed that he will not be building sewers larger than 15 or 18 in. and that the depths will not be greater than, say, 15 ft. The larger and deeper sewers present special problems that are not be covered here. Therefore, neither the design of sewers nor the techniques of setting grade stakes are considered. The matters discussed, however, apply equally to clay or concrete sewers.

Importance of Good Construction

Before getting into the details of sewer construction, it might be well to consider why good construction is important to the sewage works operator.

The first reason is that good construction will minimize maintenance. That is important; directly to the man who must maintain the sewers, or indirectly if high maintenance costs take money from the city treasury that should be spent for improvements or for salaries at the plant. Poor construction leads to cave-ins and to root growth entering the sewer.

The second reason is that infiltration can be greatly reduced by good workmanship. To accomplish this requires good specifications and good construction supervision. Many of the newer specifications for sewers contain provision for infiltration tests of completed lines in order to encourage good workmanship on the part of the contractor. A common limitation is that the infiltration must not exceed 10,000 gpd per mile of sewer.

It must be remembered that once the sewer is covered up, it is pretty hard to do anything about sloppy work. If the job is poor, the chances are good that it will be a headache for the town for many, many years.

Importance of House Sewers

The part of the sewer system that ordinarily gets the least attention is the house sewers. Just how important are the house service sewers to the sewage works operator.

A typical example would include a block 300 ft long. The streets are 80 ft wide and the sewer is constructed in the street. If the lots are 50 ft wide, there will be 12 lots (6 on each side). If the houses are set back 40 ft from the property line, each house service

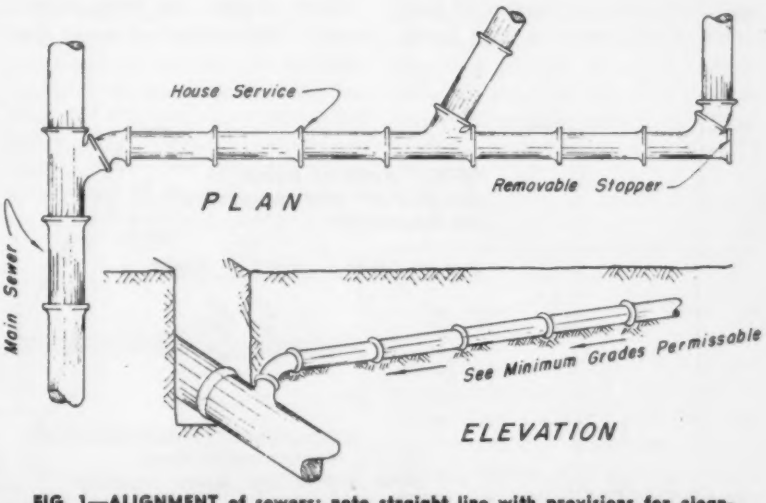


FIG. 1—ALIGNMENT of sewers; note straight line with provisions for cleaning. (Adapted from Clay Products Assn. data.)

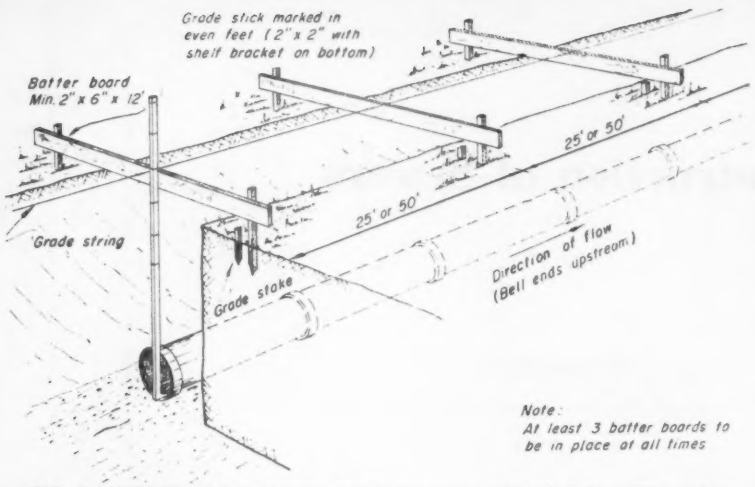

Grade stick marked in even feet (2" x 2" with shelf bracket on bottom)
Batter board Min. 2" x 6" x 12'
25' or 50'
25' or 50'
Grade string
Grade stake
Direction of flow (Bell ends upstream)
Note: At least 3 batter boards to be in place at all times

FIG. 2—METHOD of transferring grade to sewer. (Adapted from "Clay Pipe Engineering Manual.")

will be 80 long. All houses being connected, there will be a total length of house services of 12 x 80 = 960 ft for the block. The main sewer will be 380 ft long from the center of one street to the center of the next. In other words, the length of house services is 2½ times the length of the main sewer. Of all the sewers in a town which contribute flow to the plant, at least ⅔ of the total length probably would be private sewers.

Estimates of the amount of infiltration in existing systems vary over a wide range. Authorities disagree on this point, but many will agree that the amount of infiltration is controlled by the length of the sewers or the number of joints, rather than by the size of the sewer; in other words, as much infiltration can be expected from a mile of 6-in. sewer as from a mile of 18-in. If inspection is lax, there probably will be more infiltration from the 6-in. sewers. The reason for this argument is, of course, that although larger sewers have larger joints, it is easier to make a good joint on a large sewer than on a small one.

At this point it would seem wise to stress the importance of having a good permit system so that no taps can be made without authorization, and so that inspection is necessary before the excavations are backfilled. It is virtually impossible to control the quality of the work unless the inspection force has some legal authority.

Changing Economic Conditions Affecting Sewer Construction

Many changes are being experienced in the methods of sewer construction due to present-day economic conditions; because of the high cost involved, contractors have been looking for ways to cut corners. This fact must be recognized, because there must be constant alertness that the corners are not cut in the wrong places.

The principal reason for the trend is, of course, the high cost of labor. Contractors are devising means of reducing the man-hours on a job. They no longer want to have a man in the trench painstakingly shaping the bottom to fit the shape of the pipe; they must save time on making joints; they certainly do not want to hand-tamp the backfill around the pipe (or even machine tamp, for that matter); and they wouldn't consider backfilling with hand shovels.

Another noticeable factor is that contractors want to economize by using equipment that is versatile and can be used on more than one type of work. As a result, the back-hoe is used more and the trenching machine less. The result is less control of the depth and alignment, and wider trenches, because the contractor would rather move dirt by machine than put in expensive sheeting.

Importance of Planning

The need for engineering studies and over-all planning cannot be too strongly emphasized. Although this discussion covers sewer construction techniques, it must be borne in mind that the design of sewer systems or portions of systems is an engineering job. The decision to save money by not having adequate engineering studies made is all too often a very

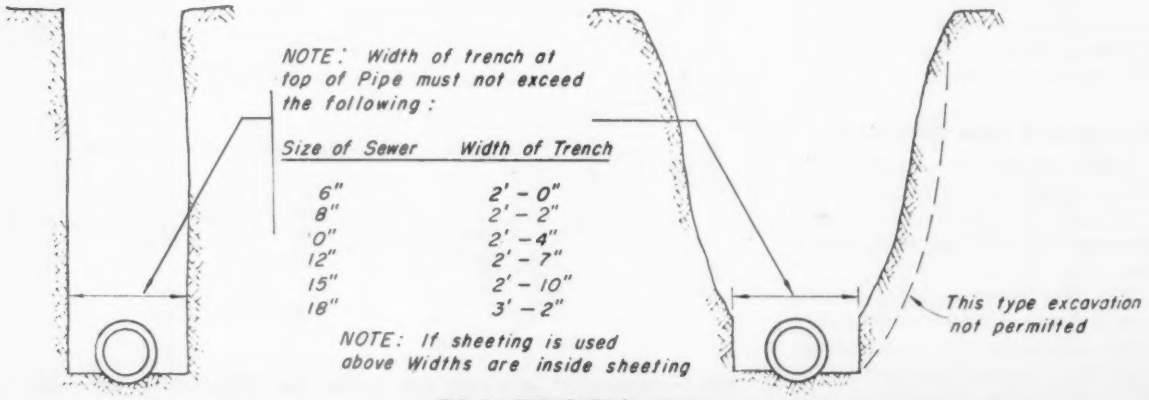

NOTE: Width of trench at top of Pipe must not exceed the following:
Size of Sewer Width of Trench
6" 2'-0"
8" 2'-2"
10" 2'-4"
12" 2'-7"
15" 2'-10"
18" 3'-2"
NOTE: If sheeting is used above Widths are inside sheeting
This type excavation not permitted

FIG. 3.—TRENCHES for sewers.

expensive decision in the long run. It is obvious, for instance, that any construction should fit into an overall plan in order that progress can be made in an orderly fashion.

Alignment of Sewers

Older sewer construction practice required that when the sewer was completed, inspection included dropping a light down one manhole and sighting up the barrel of the sewer from the next manhole. The principal advantage of this requirement was that poor construction could sometimes be detected that would otherwise go unnoticed. Very few sewers of the smaller sizes are built to that precision nowadays, regardless of what the specifications state. Such precision is not considered necessary by many people. The principal consideration is that the alignment be such that the sewers can be readily cleaned or rodded (Fig. 1). In general, there should be no break in grade or alignment between manholes for sewers 24 in. and smaller in diameter. Manholes for these sizes should not be more than 400 ft apart. The alignment of the sewers should, of course, be reasonably good in order that joints fit together properly.

Grade

In supervising construction, it is well to be certain that the pipe is laid to proper grade (see Fig. 2), particularly if the slopes are fairly flat. A hump in a sewer line can be the cause of repeated maintenance calls and expense.

Experience has shown that a flow velocity of about 2 ft per second will keep a pipe scoured and prevent solids from settling out. Experience has shown that sewers laid on grades sufficient to give this velocity when flowing half full will give little trouble from solids settling out, even though the actual flow is normally lower a good portion of the time. The following minimum slopes are acceptable:

Sewer Size, in.	*Minimum Slope, Feet per 100 ft*
6	0.6 — 7¼
8	0.4 — 4¾
10	0.28 — 3⅜
12	0.22 — 2⅝
15	0.15 — 1¾

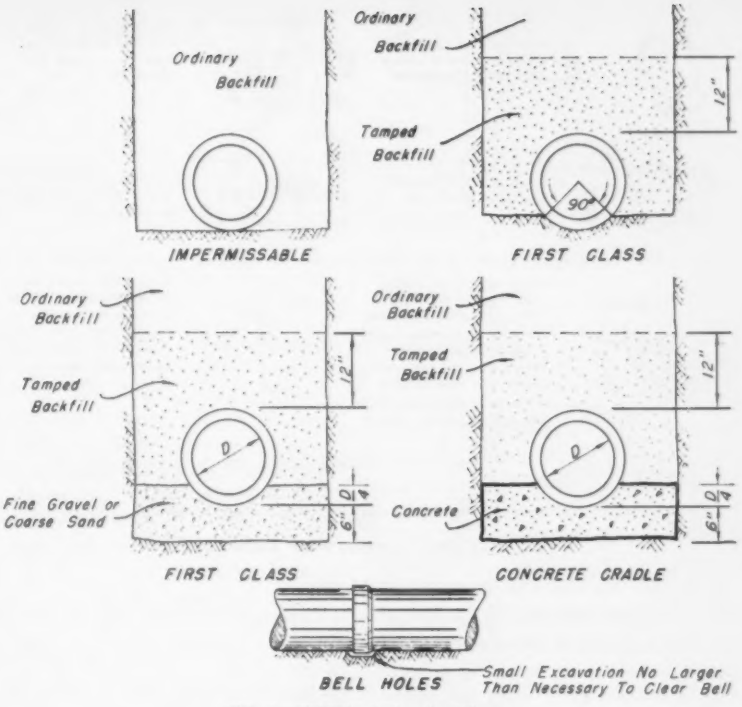


FIG. 4—TYPES of pipe bedding.

Wherever practical, slopes should be greater than the foregoing. For instance, a desirable grade for a house service is ⅛ in. per foot, or about 1 ft in 100 ft.

There is seldom any need for concern over maximum grades in sanitary sewers. Experience has shown that even very steep storm sewers show little wear because of high velocities.

The techniques used in getting the grade from the engineers' grade stake to the sewer may be of concern to those charged with inspection. Some contractors do not want to take the trouble to set up batter boards, but insist that they can do as good a job with a string on pegs driven into the sides of the trench. The only satisfactory way of doing the job is to use batter boards and to require that not less than three be in place at all times. This practice will greatly assist the inspector because he can easily check to see that the grade is correct. It also, in many instances, picks up errors in leveling or computing the cuts.

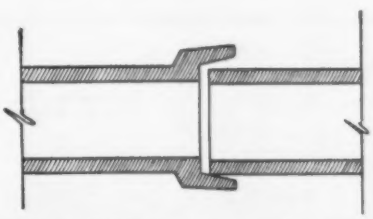


FIG. 5—SECTION through pipe joint without packing.

Trenching

The old way of digging sewer trenches was, of course, by hand shovel. If the depths were over a man's head, the trenches were sheeted and braced with anything from skeleton sheeting to solid sheeting. The trenching machine, of course, is especially built for the job. It excavates a vertical trench of uniform width and is easily controlled as to depth and alignment. The trench, of course, must be sheeted and braced, although usually not to the extent necessary with hand work because the excavations aren't open as long.

Contractors more and more are coming to use the back-hoe for trenching. The principal reason is that it is a more versatile piece of equipment. When they finish a trench job, they can change the boom and have a shovel, a crane, a dragline, or a pile driver. Nevertheless, the tendency with the back-hoe is toward sloppy

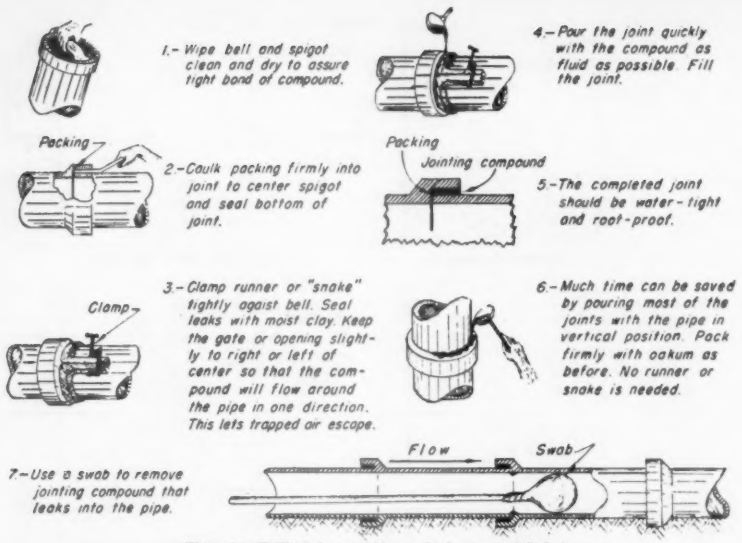

1.- Wipe bell and spigot clean and dry to assure tight bond of compound.
2.- Caulk packing firmly into joint to center spigot and seal bottom of joint.
3.- Clamp runner or "snake" tightly against bell. Seal leaks with moist clay. Keep the gate or opening slightly to right or left of center so that the compound will flow around the pipe in one direction. This lets trapped air escape.
4.- Pour the joint quickly with the compound as fluid as possible. Fill the joint.
5.- The completed joint should be water-tight and root-proof.
6.- Much time can be saved by pouring most of the joints with the pipe in vertical position. Pack firmly with oakum as before. No runner or snake is needed.
7.- Use a swab to remove jointing compound that leaks into the pipe.
Packing
Jointing compound
Clamp
Flow
Swab

FIG. 6—STEPS in making a hot poured joint.

work. A lot of dirt can be moved and still keep ahead of the tile layers, so the contractor likes to dig a wide trench with sloping sides and eliminate the need for sheeting. It is hard to hold a true grade with the hoe because each bite is controlled by the operator. A really good operator, of course, can do a pretty fair job.

An important item to watch is the width of the trench at the top of the pipe (Fig. 3). The maximum width at this point is important because it controls the load that will come on the pipe due to backfilling. If the trench is too wide at the bottom, the pipe may be permanently damaged before it is put into use.

Bedding

In order for the pipe to support the weight placed on it, it must be properly bedded for its full length. It is not sufficient to have a flat trench bottom. The bearing must be shaped to fit the contour of the pipe. This can be done by shaping the earth, by placing the pipe on a sand bed, or by placing it on a concrete cradle. Figure 4 shows four types of bedding. At ordinary depths the first class of bedding will be sufficient. At extreme depths, or because of unstable bottom, it may be necessary to use a concrete cradle.

Another important item is that of bell holes. They are necessary to see that the weight (earth pressure) is taken by the pipe and not by the bell. They must not be too large, or they will take up too much of the bearing area.

Joints

A number of materials have been devised for jointing sewer pipe. Among these are: cement mortar, hot-poured bituminous, pre-moulded joints, rubber rings, and cold-applied bituminous.

For sanitary sewers, cement mortar joints are not good; mortar shrinks when it cures and a crack is left just large enough to let in roots and, of course, water. In addition, a good joint cannot be made without a lot of care (Fig. 5). It is particularly difficult to make a good joint in a wet trench.

Hot-poured joints (Fig. 6) are perhaps the most popular, although they have limitations when used in wet trenches or in cold weather. The cold-applied joints are gaining favor. They set up in water and work well in hot or cold weather. One important consideration in any joint is that it exclude roots, either by being too hard for the roots to penetrate or by containing a chemical which will prevent root growth.

With most jointing materials it is necessary to use a packing to center the spigot in the bell. One exception is concrete pipe of the smaller sizes, sometimes made with a self-centering joint. Figure 5 shows what happens when the spigot is not centered. Jute or hemp have been widely and almost exclusively used as joint packing materials for many years. Recently, an asphalt-impregnated braided packing has been put on the market which appears to have many advantages over jute and which is claimed to be no more expensive.

Manholes

Brick manholes are almost a thing of the past. Most of the manholes built today are made of precast concrete rings or concrete blocks (Fig. 7). These manholes are easily installed and save a lot of labor on the job. When rings are used, the steps are cast in the ring. To minimize infiltration, concrete block manholes should be plastered on the outside with a ⅜-in. thickness of portland cement grout. Manhole steps should be of cast iron or aluminum. The steel rods formerly used are a safety hazard after a few years.

Manhole frames and covers are almost always of cast iron. For light traffic or no traffic, a casting weighing about 325 lb is sufficient. For heavily-traveled streets, the castings should be heavier, up to 450 to 500 lb.

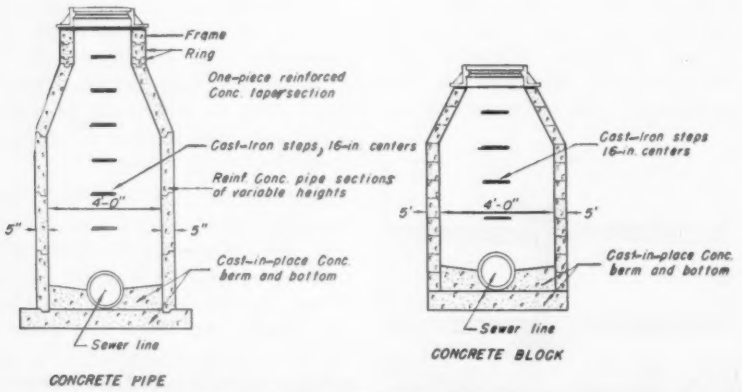


FIG. 1—TYPES of manhole construction.

Taps to Existing Sewers

One of the greatest contributors to caveins in old sewer systems is poor connections of services to the main sewer. Wherever possible, of course, taps should be made at an existing Y fitting, but if that is not possible it is necessary to break into the sewer. (The following are a few rules for making taps (Fig. 8):

1. The connection should be made in the upper half of the sewer.
2. The connecting pipe must not protrude into sewer.
3. The main sewer must not be weakened unnecessarily; if so weakened, it must be reinforced.
4. The weight of the connecting tap must not be supported by the main sewer.
5. No connection should be permitted to be backfilled until it has been properly inspected and approved.

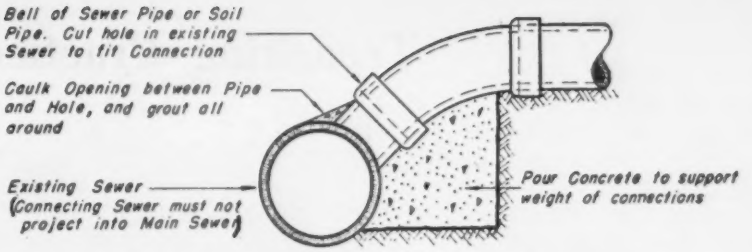

Bell of Sewer Pipe or Soil Pipe. Cut hole in existing Sewer to fit Connection
Caulk Opening between Pipe and Hole, and grout all around
Existing Sewer (Connecting Sewer must not project into Main Sewer)
Pour Concrete to support weight of connections

FIG. 8—METHOD of connecting house service line to existing sewer.

Backfill

It is extremely important that sewer trenches be backfilled properly. Otherwise, the pipe may be broken before it is put into use. Even in this machine age the portion on each side of the pipe and to a point about 12 in. over the top of the sewer should be filled by hand, and preferably tamped. Care must be taken that the backfilling operation does not disturb the pipe and that large clods or rocks do not fall on it and damage it. If granular material is imported for backfill, the tamping may be eliminated.

If prevention of settlement is important, such as where pavement is to be placed over the trench, the best method, and probably the most expensive, is to tamp the material in thin layers and at proper moisture content. Tamping at the right moisture content requires close supervision. Often, in cases of this nature, the excavated earth is hauled away and the backfill is made with sand or gravel. In most cases, where the trenches are on secondary streets, it will be cheaper and more expedient to backfill by ordinary methods and place a temporary surface for the first few months, during which most of the settlement should occur.

Water settling by jetting or ponding has been widely used to compact backfill in trenches. If the material is clay this practice should be avoided, because the loads transmitted to the pipe might be several times the normal earth loads. The reason is that the water lubricates the sides of the trench by making the clay slippery and the excess water in the soil forms a mud that acts more like a liquid than a solid. The weight of the whole mass is concentrated on the pipe, especially if the sides of the trench are sloping. Water settling in clay soils is not recommended if the depths are greater than 8 ft. If the soil is sand or gravel, water settling is ordinarily good practice and is probably the best way of getting settlement.

Record Maps

It would be hard to over-emphasize the importance of keeping good records of underground utilities. This is one matter that seldom gets enough attention, and frequently gets little or no attention. The cost of keeping the records will be saved many times over in the future, for sooner or later someone will need the information and it may cost a lot of money to get it.

Sewer records should show the size, type, depth, and date of construction of every sewer. They also should show distances to manholes, tees, wyes, connecting sewers, etc.

It is never too early or too late to start making records. Information gained now should be recorded so that it won't have to be duplicated in the future. Whenever a main is dug up, the depth, size, type, and location can easily be determined. The next time it is necessary to dig up that sewer, it won't be hard to find.

Records can be kept in many ways. Figure 9 shows one suggested method. One important suggestion is that there be more than one copy of the records, so that if one is lost it can be reproduced.

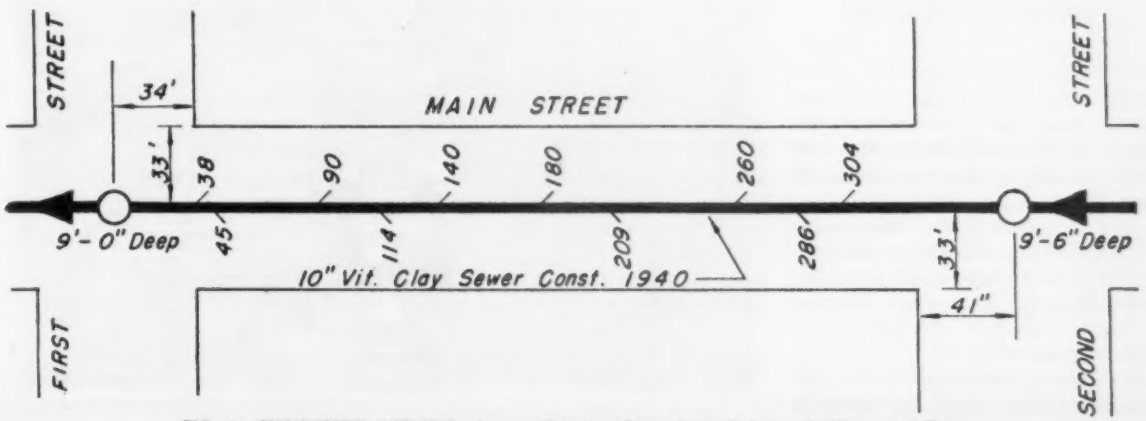


FIG. 9—SUGGESTED METHOD of recording location of manholes and Wyes and Tees.

Trenching Practice

by RICHARD BENNETT, C.E.
City Engineer, Phoenix, Ariz.

A trench is an excavation having vertical sides and considerable depth in comparison to its width. For purposes of this article it will be considered as being less than 6 ft. in width and not more than 30 ft. in depth, which permits excavation by modern trenching machinery.

Trenches are dug for all kinds of pipe lines, including water, sewer, gas, oil, drains, conduits, etc. The large amounts of trench excavation made necessary by the installation of pipe lines for the various uses has led to many improvements in this practice.

Many of the early forms of trenching machinery such as the traveling derrick, the trestle cable excavator, the tower cableway, the trestle-track excavator, etc., have all given way to the modern ladder type and wheel type trenchers.

Trenching machinery was first perfected about 1910. It gives low cost excavation plus fast rate of progress. It is a part of almost every pipe line construction job. Except for very small jobs, hand trenching labor is generally found inefficient and uneconomical. If the ground is free of large, heavy obstructions, and not too hard, the modern trencher is very efficient.

EARTH TRENCHING

The type of trencher to use will depend upon local conditions. If the trench dimensions are small, and much maneuvering is required because of restricted conditions, then some of the smaller trenchers will prove best.

Many consider the wheel type trencher is a harder digger than the ladder type. In hard tough clays, for medium depths and widths, this type is most efficient. These designs are generally limited in maximum widths and depths of trenches excavated, the maximum being about 3½ ft. width and 8½ ft. depths.

Where trenches of greater width and depths are involved, the ladder type must be used. If stones, not too large, are encountered occasionally, the ladder type is more efficient to loosen them, being partly due to the vibration of the boom, whereas the steadiness of the wheel type excavator would not accomplish the same result.

On most of the ladder type trenchers the boom may be telescoped so that the depth of the trench may be increased or decreased with little difficulty.

In any case, if the digging is difficult, then the high-powered types must be used.

Some trenchers are designed for use in cramped quarters, such as narrow alleys, parkways, close to curbs, buildings or other obstructions, etc. With some the boom may be shifted to one side so that the trench may be cut close to side obstructions.

Maximum service is desired in a trencher. They are subject to hard, grueling service, and their design should sacrifice nothing which would affect durability.

With modern trenchers the spoil bank may be located on either side of the machine, or loaded into trucks or on conveyor as desired. The spoil conveyor will place the spoil bank back from the trench sufficient distance to give a good clean shoulder on which the workmen are not hindered in laying pipe. When extensions are added to the spoil conveyor the desired height of the spoil bank may be secured to care for the earth from deep trenches.

Trenching Methods

If the trench is deeper than the trencher will excavate, there are two methods which can be used to gain extra depth without undue expense. (a) Excavate with scrapers sufficient depth from the surface and the full width of the trencher so that the trencher can excavate to desired grade line. Several feet of added trench depth can be secured in this manner. The spoil conveyor can be lengthened so that the earth may be removed either to spoil bank or to trucks as desired. (b) Under most conditions it is possible to remove about two feet of earth below the trencher cut, and throw the spoil bank back onto pipe already laid in place. Using two workmen, one with

Caterpillar Tractor Co.

PARSONS trencher making ditch for Sanitary Sewer

Oliver Corp.

SMALL utility unit has backhoe for ditching, front scoop for filling.

an air spade and the other to shovel, this work can be done at a rather rapid rate of progress. Using the combination of these two methods, several added feet of depth can be economically secured.

USE OF BACKHOES

Trenching can be done efficiently by the use of a backhoe (also known as hoe, pull-shovel, drag-shovel, etc.). Units of this general type vary from small machines with a bucket capacity of ¼ cubic yard or less, used as attachments on crawler or rubber-tired tractors, to attachments for full revolving commercial crane-shovel units, with bucket capacities from ⅜ to 2 cubic yards, or more.

Hoes are most effective in digging at or below the base of the machine, and in firm soils; they can often be used effectively in hard or rocky soils in which a trenching machine finds very rough going. They can work to straight lines with close tolerances, dig trenches with vertical sides, and conform closely to grade requirements in the bottom of the trench. Units of this type are effective in digging narrow, deep trenches and can be used to excavate wide, shallow ditches, athough less effectively. Maximum digging depth for crane-shovel units fitted with backhoe attachments is frequently more than 20 feet below ground level.

Production rates for trenching operations vary so widely that it is nearly impossible to give typical figures. A rough estimate is that the production will vary from 50 to 100 percent of that of a shovel of comparable size loading into trucks. In excavating shallow trenches with a spoil bank on one side of the ditch (the usual procedure), the backhoe has a fast cycle, although the bucket generally fills poorly and frequent moves are time consuming. In digging excessively narrow trenches, the bucket efficiency is low. In work on deep trenches, the bucket fills well, there are infrequent moves, but the cycle is comparatively slow.

Insley Mfg. Co.

CRAWLER MOUNTED BACKHOE on Pipeline Trenching

Herbert L. Nichols, Jr., in his authoritative book *Moving The Earth*, makes the following suggestions for efficient backhoe operation.

1. Keep bucket teeth sharp and built up to proper size.
2. Line shovel up to cut outer edges of excavation in a straight line.
3. In deep digging, keep a fairly straight face and keep shovel back from it as far as possible. Don't work on a "peninsula" which may cave.
4. Keep knocking the spoil pile back as you dump on it. You may need the space.
5. Don't dig yourself into a trap—the spoil pile may slump across your way out.
6. Don't let the drag slide the shovel into trouble when the bucket hooks something solid.
7. Dont' work with the drag cable in the dirt. If a pile builds up in front of the tracks, back away and knock it off.
8. Try to keep the shovel higher than the trucks it is loading.
9. Don't pull boom back on top of shovel with drag or hoist.
10. Keep boom low while walking, or while swinging uphill.
11. Don't walk, or swing uphill, when drag cable is slack.

ROCK TRENCHING

What was said on trench excavation in dirt may also be almost wholly applied to trenching in rock. Rock trenching is a time and labor consuming proposition. The fact that it is not often encountered probably accounts for the great variation of methods adopted on different jobs.

System Lacking

Most rock trenching jobs have little or no system. Costs are high, progress is slow, and those in charge make little or no endeavor to find the most economical method for that job.

In rock trenching the quality and quantity of the rock will generally determine the proper method of excavation. For economical work it is necessary to give much thought and attention to the job methods.

The types of rock encountered may vary from hardpan to dense, tough granites; each will require a different method of drilling and shooting.

Drilling Requirements

The number of feet of hole to be drilled per cubic yard of rock to be excavated will vary greatly with different jobs, conditions, and job methods. Spacing will depend upon nature of the rock and width of trench. Properly determining this factor requires much ability on the part of the job manager. This determines ultimate unit costs.

For average rock the following table may be used to determine trial hole spacing:

Width of trench (feet)	Number of rows of holes
3	2
6	3
9	4
12	5
15	6

The outside row of holes should be in line with the trench wall. It is seldom that cross-trench hole spacing greater than 3 ft. can be successfully used. At times the longitudinal spacing can be increased to 4 ft. or even slightly more, especially in the wider and deep trenches. The greatest economy is secured in using maximum depth for holes.

The necessity for protecting adjacent structures, whether underground utilities or nearby buildings, will influence drill hole spacing.

If power excavation equipment is to be used, it is seldom possible to blast a single line of holes down the center of the trench. With but one line of holes too much projecting rock remains to be loosened by prying and barring by hand methods, thus greatly increasing costs.

Care must be taken to keep the drill holes clean until they are loaded. If the hole contains debris or water, this is best removed with compressed air. Ice frozen holes may be cleaned out with steam; this also warms the hole sufficiently so that the explosive will not freeze. A wooden plug should be driven into each hole as soon as the drilling is completed, to keep out extraneous materials; this plug also aids in finding the hole later.

Quantity of Explosives

In trench blasting only one narrow face is open, therefore more explosive is required than for open surface blasting. The amount and strength of dynamite to properly use will depend upon all the factors mentioned for spacing of drill holes. The amount of explosive required per cubic yard of rock removed will depend upon the nature and type of rock and the method adopted. The amount of explosive per hole may be limited by the necessity for controlling flying rock, excessive noise or vibrations, and danger to nearby underground utilities or adjacent structures of any nature.

ELECTRIC jack-hammer for rock excavation.

Dynamite is generally used for trench blasting; the grade used depending upon the type and quality of rock encountered. The quantity required may range from about ¾ lb. per cubic yard in soft sandstone to 3 lbs. or more in the hard, dense rocks.

Different rocks and formations do not blast alike to meet given conditions. The specifications for the work may limit the amount and kind of blasting that may be done on the job. Oftentimes blasting is restricted due to local conditions.

Quality of Explosives

The type of explosive to use will depend upon the type and quality of the rock; local conditions; etc. The greatest waste in explosives is in using a grade or type not suited to the job at hand. A low grade of explosive should be used for soft, weathered rock; to use high grade explosive here, is to waste much of the explosive energy. High power explosives lack propelling power when used in blasting soft rocks.

Too many use only one type and grade of explosive—generally 40 per cent strength. This is poor economy. Some arbitrarily use 60 per cent to secure sufficient shattering and also to loosen rock bound in place. If the rock is not shattered sufficiently, then a higher grade should be used. If the rock is shattered too much, then a lower grade should be adopted for the job.

A high power explosive should be used for hard, firm rock. If the bottom of the hole does not shoot properly, then it may be best to use a high grade explosive at this point. In such cases place the firing charge at the top of explosives so that the explosive gases will tend to concentrate at the bottom of the hole, thus producing greater rupture at that point.

Sufficient shattering must be secured to permit easy removal of the rock from the trench. It is not possible to use ladder type of trenchers for rock trenching, except in the very soft formations. A pull shovel or trench-hoe may often be used to good advantage in rock trenching.

Rock Excavating Equipment

In shallow trenches the rock may be removed by hand. For hand excavation the rock must be broken into small pieces by either blasting or subsequent breakage.

For deep rock trenches the use of drag line or pull-shovel is most economical. These types of equipment are well suited for this work. The rock must be thoroughly broken up, and the wall sufficiently straight not to hang up the shovel. Rocks too large to be removed by the bucket should be hoisted from the trench with chains.

Limestone is easily drilled. It is occasionally found in horizontal layers, and may be blasted like building stone. In seamy formations, the holes must be closely spaced to retain the force of the explosion. Seamy rocks permit the explosive gases to escape and the full effect is not retained in shattering.

Granite and igneous rocks break out in rough, irregular walls. If the holes are thoroughly and tightly tamped, then the explosive will give most effective results, due to confining the explosive gases. Trap and quartzite are generally difficult to drill.

Two factors should be kept in mind at all times in rock trench excavation; the number of feet of hole drilled per cubic yard of neat excavation; and the amount and strength of dynamite used per cubic yard of excavation; both of which sum up to: cost of breaking up the rock for satisfactory removal.

"IT'S A SNAP" *with* The Wheeler Cutter

Available in both the heavy duty hand model or the new hydraulic model. The cutters can be used in a ditch to cut pipe in a line with minimum clearance. All thats required is room to wrap the chain around the pipe.

NO VISE – NO TURNING – JUST SQUEEZE AND POP

HEAVY DUTY CUTTER
less than one minute per cut

ASBESTOS CEMENT PIPE
Rd. or oval 4" thru 15" diameter fluepipe, sewer pipe, vent pipe and conduit.

ASBESTOS CEMENT WATER PIPE
4" and 6"

SOIL PIPE
2" thru 6" std. or XH

DURIRON
2" thru 8"

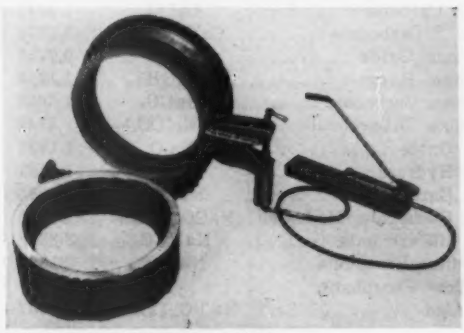
CLAY PIPE
TERRA COTTA
CONCRETE PIPE

NOTE: the same tool cuts all of the above pipe using the same wheels.

(PATS. ISSUED AND PENDING)

IMPORTANT ANNOUNCEMENT! With the newly developed auxiliary ram assembly, the hydraulic model will now cut larger sizes of cast iron water main.

Cutter with Auxiliary Ram Assembly in Place on 16" Cast Iron Water Main



THE HYDRAULIC MODEL CUTS

- CLASS 150 AWWA WATER MAIN 4" thru 18"*
- CLASS 250 AWWA WATER MAIN 4" thru 18"*
- CEMENT LINED CAST IRON WATER MAIN 4" thru 18"*
- STD OR XH SOIL PIPE 6" thru 18"
- ASBESTOS CEMENT PRESSURE PIPE 6" thru 15"
- TERRA COTTA OR TILE PIPE 6" thru 36" (with extra chain)

(Sizes Greater Than 12" Require Auxiliary Ram)

The Wheeler Mfg. Corporation - Box 688 - Ashtabula, Ohio

Alkalinity Equivalents

AMONG the mineral compounds present in natural waters, Calcium Carbonate is the most ubiquitous. Partly for this reason and partly because its molecular weight at the time, was thought to be exactly 100, this compound was chosen as the standard to be employed in the measurement of alkalinity and hardness.

With more accurate determination of atomic weights, the molecular weight of Calcium Carbonate is now assumed to be 100.08. Very obviously, tables earlier prepared under the assumption that the molecular weight was 100 will have a small and not entirely negligible error if the true weight be 100.08. The accompanying table, based upon the newer molecular weight of 100.08 for Calcium Carbonate, are arranged in such manner as to facilitate comparisons against other substances having different values of alkalinity. These values are presented as being more accurate than those appearing in earlier tables computed on the old 100 molecular weight value assumed for Calcium Carbonate.

A brief explanation of how the tables may be used follows.

In the sixth column, sixth line, the unity of Calcium Carbonate may be compared directly against every other factor in the column. For instance, one part of alkalinity, due to Calcium Carbonate, is the exact equivalent, in alkalinity value, to that which would be imparted by 1.6196 of Calcium Bicarbonate; 0.7403 of Calcium Hydroxide; 0.8424 of Magnesium Carbonate; 1.0590 of Sodium Carbonate (dehydrated), etc.

Along the line, right or left, a different comparison may be made. The molecular weight, for instance, of Calcium Bicarbonate, is in excess of that of Calcium Carbonate. Therefore, it takes more Calcium Bicarbonate to produce a given alkalinity than it does of Calcium Carbonate, and it is found that for an equal weight of Calcium Bicarbonate the alkalinity value as compared against Calcium Carbonate is only 0.6174 parts. On the other side an equal weight of Calcium Hydrate will have an alkalinity value of 1.3506 parts; Sodium Hydroxide 1.2508—and so on.

From the foregoing it is seen that the compounds in these tables may be compared in two different ways against the Calcium Carbonate Standard for alkalinity, or against any other compound in the table. For instance, under the heading Sodium Hydroxide (NaOH) it is noted that one part is equal in alkalinity value to 1.3247 parts of Sodium Carbonate (Soda Ash); and, further, that one part of Sodium Carbonate is only equal to 0.9442 parts of Calcium Carbonate in raising alkalinity values.

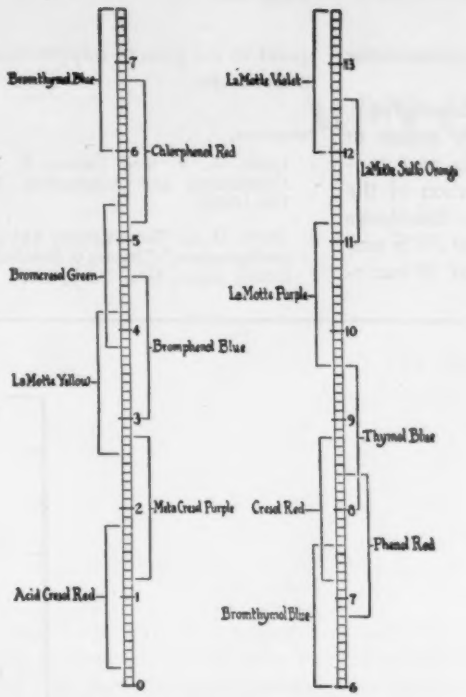
ALKALINITY EQUIVALENTS*

Compound	Formula	$Al_2(OH)_6$	BaO	$Ba(OH)_2$	CaO	$Ca(OH)_2$	$CaCO_3$	$CaH_2(CO_3)_2$	MgO	$Mg(OH)_2$
Aluminum Hydrate	$Al_2(OH)_6$	*1.0000*	0.3390	0.3034	0.9271	0.7017	0.5195	0.3207	1.2895	0.8913
Barium Oxide	BaO	2.9494	*1.0000*	0.8948	2.7734	2.0697	1.5323	0.9461	3.8035	2.6289
Barium Hydrate	$Ba(OH)_2$	3.2959	1.1174	*1.0000*	3.0559	2.3128	1.7123	1.0572	4.2503	2.9377
Calcium Oxide	CaO	1.0785	0.3656	0.3272	*1.0000*	0.7568	0.5603	0.3459	1.3908	0.9613
Calcium Hydrate	$Ca(OH)_2$	1.4250	0.4831	0.4323	1.3212	*1.0000*	0.7403	0.4571	1.8376	1.2701
Calcium Carbonate	$CaCO_3$	1.9247	0.6525	0.5839	1.7845	1.3506	*1.0000*	0.6174	2.4821	1.7155
Calcium BiCarbonate	$CaH_2(CO_3)_2$	3.1174	1.0569	0.9458	2.8904	2.1876	1.6196	*1.0000*	4.0202	2.7786
Magnesium Oxide	MgO	0.7754	0.2629	0.2352	0.7189	0.5441	0.4028	0.2487	*1.0000*	0.6911
Magnesium Hydrate	$Mg(OH)_2$	1.1219	0.3803	0.3403	1.0402	0.7873	0.5828	0.3598	1.4468	*1.0000*
Magnesium Carbonate	$MgCO_3$	1.6216	0.5498	0.4920	1.5035	1.1379	0.8425	0.5201	2.0912	1.4454
Magnesium BiCarbonate	$MgH_2(CO_3)_2$	2.8143	0.9541	0.8538	2.6094	1.9749	1.4621	0.9027	3.6293	2.5085
Sodium Oxide	Na_2O	1.1922	0.4042	0.3617	1.1054	0.8366	0.6194	0.3824	1.5375	1.0627
Sodium Hydrate	NaOH	1.5387	0.5217	0.4668	1.4267	1.0798	0.7994	0.4935	1.9843	1.3715
Sodium Carbonate	Na_2CO_3	2.0385	0.6911	0.6184	1.8900	1.4305	1.0590	0.6538	2.6288	1.8169
Sodium Carbonate, Hydrated	$NaCO_3,10H_2O$	5.5033	1.8658	1.6697	5.1025	3.8619	2.8592	1.7653	7.0969	4.9052
Sodium BiCarbonate	$NaHCO_3$	3.2312	1.0955	0.9803	2.9958	2.2674	1.6787	1.0364	4.1669	2.8800
*Tri-Sodium Phosphate	Na_3PO_4	2.1028	0.7129	0.6380	1.9497	1.4756	1.0925	0.6745	2.7118	1.8743
Tri-Sodium Phosphate, Hydrated	$Na_3PO_4,12H_2O$	4.8747	1.6527	1.4790	4.5197	3.4207	2.5326	1.5636	6.2863	4.3449

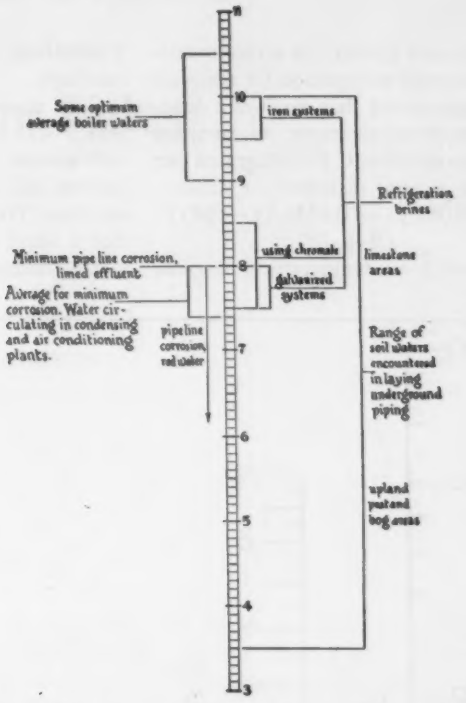
Compound	Formula	$MgCO_3$	$(CO_3)_2$	Na_2O	NaOH	Na_2CO_3	Na_2CO_3, $10H_2O$	$NaHCO_3$	Na_3PO_4	Na_3PO_4, $12H_2O$
Aluminum Hydrate	$Al_2(OH)_6$	0.6166	0.3553	0.8387	0.6498	0.4905	0.1817	0.3094	0.4755	0.2151
Barium Oxide	BaO	1.8187	1.0480	2.4737	1.9167	1.4468	0.5359	0.9128	1.4025	0.6050
Barium Hydrate	$Ba(OH)_2$	2.0324	1.1711	2.7643	2.1419	1.6168	0.5989	1.0200	1.5672	0.6761
Calcium Oxide	CaO	0.6650	0.3832	0.9046	0.7009	0.5290	0.1959	0.3337	0.5128	0.2212
Calcium Hydrate	$Ca(OH)_2$	0.8787	0.5063	1.1952	0.9260	0.6990	0.2589	0.4410	0.6776	0.2923
Calcium Carbonate	$CaCO_3$	1.1869	0.6839	1.6143	1.2508	0.9442	0.3497	0.5956	0.9152	0.3948
Calcium BiCarbonate	$CaH_2(CO_3)_2$	1.9223	1.1076	2.6146	2.0259	1.5292	0.5664	0.9647	1.4824	0.6395
Magnesium Oxide	MgO	0.4781	0.2755	0.6503	0.5039	0.3803	0.1409	0.2399	0.3687	0.1590
Magnesium Hydrate	$Mg(OH)_2$	0.6918	0.3986	0.9409	0.7291	0.5503	0.2038	0.3472	0.5334	0.2301
Magnesium Carbonate	$MgCO_3$	*1.0000*	0.5762	1.3601	1.0538	0.7955	0.2946	0.5018	0.7711	0.3326
Magnesium BiCarbonate	$MgH_2(CO_3)_2$	1.7354	*1.0000*	2.3604	1.8289	1.3806	0.5113	0.8709	1.3382	0.5773
Sodium Oxide	Na_2O	0.7352	0.4236	*1.0000*	0.7748	0.5848	0.2166	0.3689	0.5669	0.2445
Sodium Hydrate	NaOH	0.9488	0.5467	1.2906	*1.0000*	0.7548	0.2796	0.4762	0.7317	0.3156
Sodium Carbonate	Na_2CO_3	1.2570	0.7243	1.7097	1.3247	*1.0000*	0.3704	0.6308	0.9693	0.4181
Sodium Carbonate, Hydrated	$NaCO_3,10H_2O$	3.3936	1.9554	4.6157	3.5764	2.6996	*1.0000*	1.7031	2.6169	1.1289
Sodium BiCarbonate	$NaHCO_3$	1.9925	1.1481	2.7100	2.0998	1.3850	0.5871	*1.0000*	1.5364	0.6628
Tri-Sodium Phosphate	Na_3PO_4	1.2967	0.7471	1.7637	1.3665	1.0315	0.3821	0.6504	*1.0000*	0.4313
Tri-Sodium Phosphate, Hydrated	$Na_3PO_4,12H_2O$	3.0059	1.7320	4.0885	3.1679	2.3913	0.8857	1.5078	2.3181	*1.0000*

* Prepared by the late C. Arthur Brown, of Lorain, Ohio.

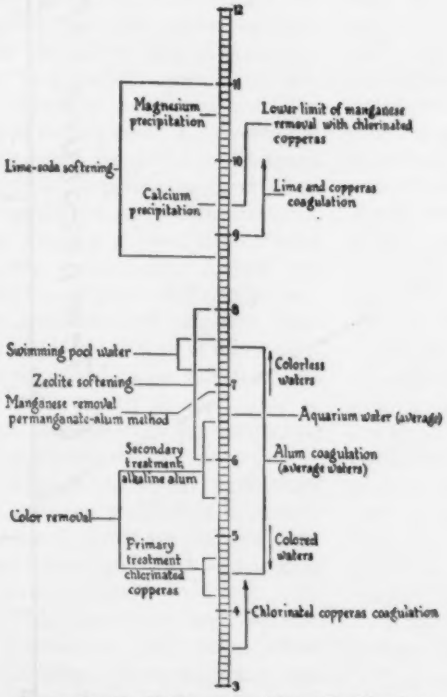
pH Zones in Water and Sewage Treatment*



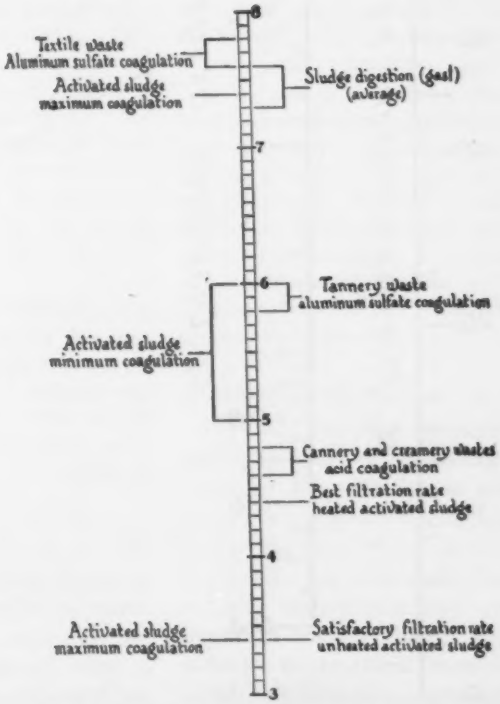
Ranges of Selected Indicators for PH Determination


Some optimum average boiler waters
iron systems
Refrigeration brines
Minimum pipe line corrosion, limed effluent
using chromate
limestone areas
Average for minimum corrosion. Water circulating in condensing and air conditioning plants.
galvanized systems
pipeline corrosion, red water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification


Textile waste
Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (gas) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes acid coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

Oxygen Dissolved in Water

by D. S. DAVIS

Head, Dept. Pulp & Paper Technology University of Alabama, Tuscaloosa, Ala.

Ippen and Carver,[1] in a recent article, presented an equation for use with an oxygen meter that employs a dropping mercury electrode, to compute the concentration C in milligrams per liter of oxygen dissolved in water:

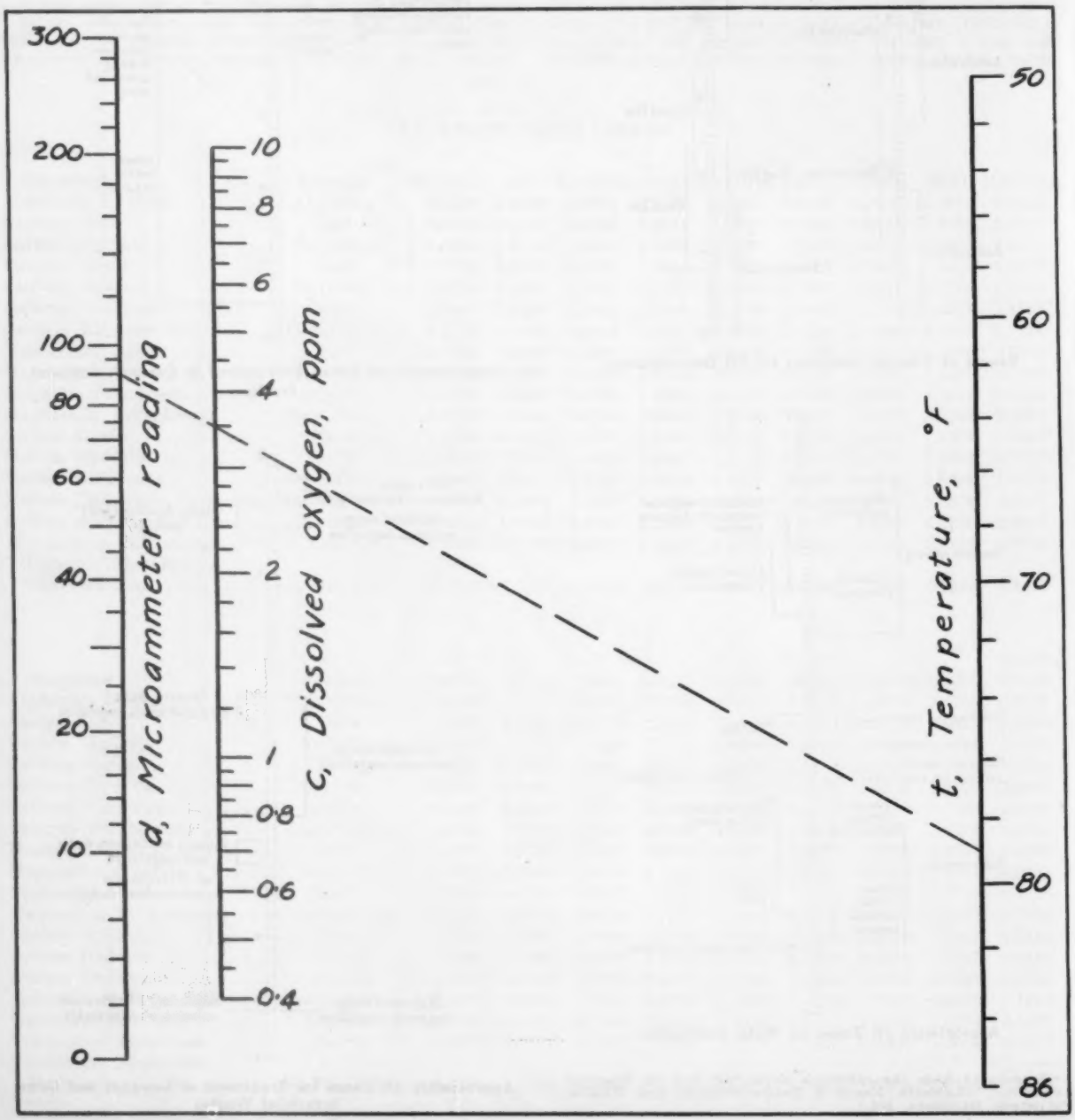
$$C = 0.040\,[1 - 0.0116\,(t - 68)]\,(d + 10)$$

Where t = temperature, degrees Fahrenheit, and d = microammeter readings.

The accompanying nomograph, which was constructed by means of well-known methods,[2] aids in a convenient and accurate solution of the equation. The broken index line shows that a water temperature of 79°F and a microammeter reading of 90 correspond to 3.5 ppm of oxygen dissolved in the water.

References:

1. Ippen, A. T., and Carver, C. E., Jr., Instruments and Automation, 27 (1) 128 (1954).
2. Davis, D. S., "Nomography and Empirical Equations," Chapter 6, Reinhold Publishing Corp., New York, 1955.



MPN Coliform Index

by EDMUND J. LAUBUSCH
Sanitary Engineer, The Chlorine Institute, New York, N.Y.

Inherent limitations in the application of fermentation tube test methods in bacteriological examinations of water, and consequent difficulties in their mathematical and practical interpretation, generally are unrecognized by more recent entrants into the specialized field of water resources and quality control. Others, more intimately associated with the historical development of conventional technics, often are prone to disregard or overlook the principles involved in their application and interpretation, thereby reaching dubious and ofttimes misleading conclusions. A brief recapitulation of some of the more pertinent considerations appears warranted and is the subject of this report.

The following major questions are timely with regard to application of dilution tube technics for estimating coliform density:

1. What is the actual significance of the coliform population in water?
2. How accurate are the usual coliform estimates, and what contributing factors are involved?
3. What technic is most satisfactory (consistent with time, effort, reproducibility, expense, etc.), and what degree of precision can be anticipated?

Basis of Coliform Sampling

Consideration of the actual sanitary significance of the coliform population in water as a yardstick of pollution is a complete subject in itself and is outside the scope of this discussion. It is important to remember, however, that much controversy yet exists on the subject. Objections have been particularly apparent over the past decade, attributable largely to problems associated with the newer concepts of an ever-changing environment, to unbiased and substantiated scientific observations, and to epidemiologic conjecture postulated since the acceptance of the coliform group of organisms (or their equivalent) as indexes of pollution and yardsticks of sanitary quality.

Current usage of the coliform group of organisms in appraising the bacteriological safety of water is based on the hypothesis that their numbers are considered a fair index of the extent of intestinal pollution, and their presence is considered as valid evidence that the water has been subject to pollution. Research is indicated to explore further the dynamics of coliform indexes for describing and establishing the sanitary quality of water.

The validity of the results of bacteriological examinations of water is influenced by certain necessary assumptions in sampling, as well as by the technics of analysis employed. In applying the results of bacteriological examinations on a practical basis it is considered, of necessity, that the sample collected and examined is representative of the water quality during the interval between consecutive samplings at the same point. (The frequency of sampling itself is dependent on local requirements and subject to considerable variation.)

It is further considered that the distribution of sampling points is such as to give a true picture of the bacteriological quality of the total water supply system. Although these considerations are fundamental and necessary to the evolution of quantitative and qualitative criteria of safety, it is recognized that they are not unequivocally applicable.

Limitations of Conventional Technics

It would not be warranted, of course, to design or utilize a methodology for determination of coliform density which yields results more accurate than those which can be realistically achieved within the limits of ordinary experimental and personal sources of variance. Indeed, the most elaborate mathematical formulas proposed, and there have been many over the past forty years, do not appear to approach this limit of accuracy.

It is a fact so well-established as to require no further discussion that the results of a bacteriological examination of a sample of water should be correlated, wherever possible, with a sanitary survey to enable a just estimate of the sanitary quality of that supply. With full appreciation of this, standards of water quality are defined solely on the quantitative results of laboratory examinations in recognition of the impracticality of including such a requirement.

Over the years, in developing standards, proponents have emphasized the inherent dangers of rigid and automatic application and have recommended professional judgment and discretion in the interpretation of laboratory results—a recognition too often neglected by those responsible for evaluation or certification of the safety of a water supply. Such a recommendation takes cognizance of the fact that the relation which the bacterial estimate bears to the actual safety of a water supply is variable and, to some extent, indeterminate.

For MPN determinations, the minimum number of tubes planted for a sample is governed principally by the facilities available, and the time required for the analysis commensurate with the value of the results achieved.* In practice, considerable variation is observed; however, the bacteriologic standard is so phrased as to permit quantitative interpretation of results on the basis of five 10-ml portions per sample. As few as one or as many as five portions are generally planted, and the number of dilutions, if any, is based on a knowledge of the sanitary history of the water being sampled.

The currently accepted "Standards,"[7] which involve planting of a minimum of five 10-ml portions, were not altogether accidental. There appears to be no rational basis in the establishment of a minimum of five portions, rather than say ten or more, except that it is necessary to limit the amount of labor and materials involved to such an extent that the results are commensurate with the requisite accuracy—an entirely reasonable approach.

The most accurate method of evaluating fermentation tube test results in terms of a determinate number is still open to dispute, although in more recent years this is less obvious due to the general acceptance and convenience of tables of most probable numbers from the Hoskins[4] adaptation of the Reed[8] formula based on the Poisson random distribution. The discussion which follows relates to limitations in the interpretative value of the coliform density so derived.

Evolution of MPN Technic

Bacterial population estimates based on the presence or absence of growth in tubes had an early origin, although utilization in sanitary bacteriology was realized only a few decades ago.

The Phelps Index was used extensively for many years before the advent of the MPN method of estimating coliform concentration in water. The method was based on the concept that the coliform density per ml is the reciprocal of the sample volume contained in the smallest portion (or highest dilution) showing growth. A completely uniform distribution of organisms in the sample was assumed, and the probability that gas-positive portions of the highest dilution of the sample may contain more than one organism (resulting in a density estimate lower than the true value) was neglected. Moreover, in instances where growth is obtained in a dilution higher than one in which none is obtained, interpretation is arbitrary. It is apparent that the Phelps Index does not apply to the case of multiple-dilution tests or, for that matter, to more than one tube in each of a series of dilutions.

McCrady[5] is credited with the original approach, about 1915, to the problem of estimating bacterial population from dilution tests utilizing the statistical probability theory. Shortly thereafter others[3,4,8] became interested in the interpretation of dilution data based on random and independent distribution of organisms in the sample and introduced formulas and graphs to facilitate application of their theories. It is interesting to note that Gordon,[2] in 1938, took issue with this rather consistent and uniform approach by questioning the validity of the common sampling assumption that individual bacteria are distributed independently at random, and proposed a method which he believed less affected by bias attributable to this source. In the intervening years, there have been no radical departures advanced in challenge to proponents of the original statistical theories.

Validity of MPN Estimates

Application of the MPN technic is based on the following assumptions:

1. Organisms in the sample are distributed at random.
2. Organisms exist independently of each other.
3. A single organism is sufficient to give a positive test.

In some instances all these may apply; in other instances they are completely lacking.

The validity of the maximum likelihood estimate (MPN) of the coliform density in a water sample by the conventional fermentation tube method depends, in considerable measure, on the sequence of dilutions of the sample inoculated. Two typical examples follow.

TABLE 1

Combinations of Growth-Positive and Growth-Negative Fermentation Tubes When a Single Tube Is Inoculated in Three Dilutions in Geometric Series*

Case	10 ml	1 ml	0.1 ml	MPN/100 ml
a	+	+	+	> 240
b	+	+	—	240
c	+	—	+	95
d	+	—	—	23
e	—	+	+	19
f	—	+	—	9.4
g	—	—	+	9.0
h	—	—	—	< 9.0

*From Hoskins' tables of MPN's[4].

* In the "1914 Drinking Water Standards," applicable to waters supplied for the public by interstate carriers, it was recommended that five 10-ml portions be planted, and routinely, one 1-ml and 0.1-ml portion of each sample also be planted to "demonstrate more fully the extent of pollution in grossly polluted samples." In the "1925 Standards," less emphasis was placed on the latter recommendation in recognition of the lesser range of pollution anticipated for waters offered for certification. In the "1946 Standards" the multiple-portion, geometric dilution series planting was recommended when three or more of the five equal 10-ml portions showed the presence of organisms of the coliform group, and when waters of unknown quality were being examined.

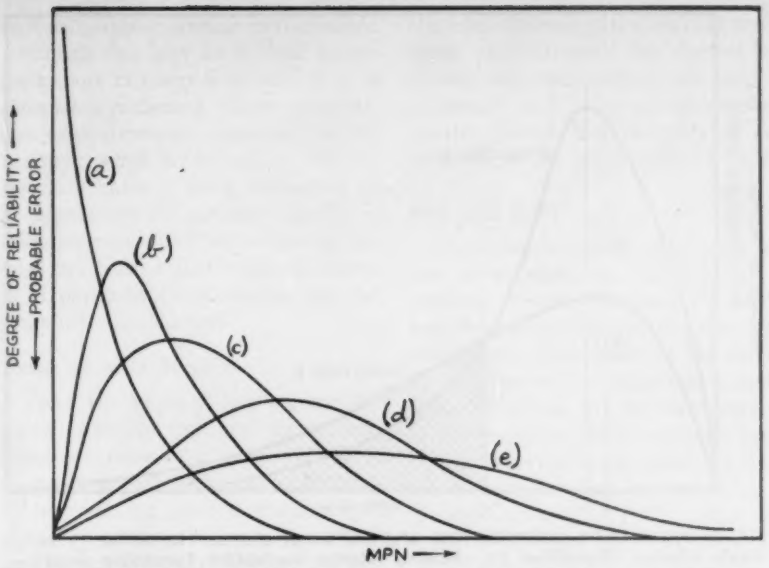


Fig. 1—PROBABILITY CURVES: Single-dilution technic with five 10-ml portions inoculated.

Condition I

(N number of tubes in each of three dilutions in geometric series). A common procedure especially adaptable to the analysis of a non-potable water sample, sewage, shellfish, etc., consists of inoculating one or more tubes in each of three dilutions in geometric series; for example, 10 ml, 1 ml, and 0.1 ml. The cases likely to arise when a single tube is planted in each of these three dilutions (a 1-1-1 test) are shown in Table 1.

These cases are listed according to the value of the MPN. Cases c, e, f, and g are anomalies but are not infrequent occurrences; they are, as Reed[8] implies, as logical as are the other cases. Cases c and f, however, are about 10 times more common than g, and almost 100 times more common than e. Cases a and h are indeterminate and are likely to develop when the coliform density is very high or very low.

The rapid changes in these MPN's indicate that the yardstick employed in the instance of the multiple-geometric dilution series for estimating coliform population is not very refined. In such a series the lowest determinate MPN obtainable from only one positive 10-ml tube is 23 per 100 ml (1/1-0/1-0/1); the range extends to 240 per 100 ml (1/1-1/1-0/1). On the other hand, for a 5-5-5 series, the lowest MPN obtainable from one positive 10-ml tube is 2 per 100 ml (1/5-0/5-0/5), and the range extends to 1,600 per 100 ml (5/5-5/5-4/5). The rather obvious conclusion follows, as shown in Table 2 that an increase in the number of portions planted in a geometric dilution series does tend to give a better measure of the MPN.

Condition II

(N number of tubes in a single dilution). The relationship between the MPN and analytical findings when N equal portions of a sample are examined is relatively simple in comparison to Condition I or when a random number of tubes at different dilutions are inoculated with random portions of sample.

The current standards for waterworks practice provide for at least five 10-ml tubes to be tested. The cases likely to arise are shown in Table 3.

Reed's plot[8] of the frequency distribution for each of the above cases, typified by Fig. 1, clearly shows that this technic is particularly applicable for measuring a relatively narrow range of pollution (as measured by MPN), and that the refinement is considerably greater, for example, than that for an equivalent number of tubes in geometric series (Condition I). The deficiency can be reduced somewhat by increasing the size of the five uniform portions to, say 100 ml, where the corresponding range would be between 0.22 and 1.6 organisms per 100 ml.

Analyzing the relative variability between Condition I and Condition II: for the latter when only one of the 10-ml portions is positive (Case b), the MPN is 2.2 per 100 ml; for the former (Case d), the MPN is 2.3 when a 100-ml portion is positive and all higher dilutions (lower concentration) are negative. If Reed's frequency curves for these two conditions are compared (Fig. 2), it becomes apparent that although the modes (MPN's) of the two are essentially the same, the curve for the multiple-dilution series technic is much broader than that for the single-dilution series.

The MPN, representing the mode in a probability or frequency distribution, gives no indication whatever of the form of the distribution. Thus, although each specific condition suggests approximately equal degrees of pollution, the probable error for the geometric series technic (I) is considerably greater than that for the single-dilution procedure (II) outlined by "Standard Methods."[9]

This also may be demonstrated by examining the area of the curve (a measure of probability) greater than the MPN represented by the vertical axis, x, shown in Fig. 2. For Condition I, the area is obviously considerably greater than that for Condition II, again indicating that the probability that the MPN exceeds x is much greater when the geometric series technic is employed than when only one dilution is used. Thus, if the bacterial density of the sample can be

TABLE 2

Probable Limits of MPN When More Than a Single Fermentation Tube Is Inoculated in Three Dilutions in Geometric Series*

No. Tubes In Series	(Lower Limit)		(Upper Limit)	
	No. Tubes	MPN/100 ml	No. Tubes	MPN/100 ml
1-1-1	1/1-0/1-0/1	23	1/1-1/1-0/1	240
2-2-2	1/2-0/2-0/2	6.0	2/2-2/2-1/2	700
3-3-3	1/3-0/3-0/3	3.6	3/3-3/3-2/3	1,100
4-4-4	1/4-0/4-0/4	2.6	4/4-4/4-3/4	1,400
5-5-5	1/5-0/5-0/5	2.0	5/5-5/5-4/5	1,600

*From Hoskins' tables of MPN's[4].

roughly estimated, the use of three or more dilutions in an indiscriminate range contributes little to the accuracy of the final result.

Interpretation

It is apparent that although the MPN index is a valuable device for placing the bacterial density estimate in terms of a discrete number, all MPN's obviously are neither equally reliable nor do they represent the actual density of organisms in the sample. At best the MPN is only approximate, especially when the number of tubes, N, is small, the reliability increasing with increasing values of N.

Thomas *et al.*[10,11] have established that the precision of a multidilution MPN test depends on the number of tubes observed in each dilution rather than on the bacterial density, and that the standard sampling error may be made comparatively small if a large number of replicate tubes are tested.

They also demonstrated that the "apparent" coliform density, based on the arithmetic mean of a series of MPN's, often is greater than the "true" coliform density because of the bias of an MPN estimate, a function of the number of tubes planted in each dilution. Their statistical computations suggest that the amount of bias is in the magnitude of approximately 23 per cent (higher than the "true" density) for a series of 5-5-5 tube tests and 43 per cent for a series of 3-3-3 tests on the same sample (based on the "Standard Methods"[9] completed test). That is, if a large number of replicate 5-5-5 tubes are examined from water containing a true coliform density of 100 per 100 ml, on the average the arithmetic mean or apparent MPN will be 123 instead of 100. A disparity of such magnitude obviously cannot be overlooked.

In interpreting the results of fermentation tube data, it also should be remembered that the MPN, representing merely a mathematical attempt to define a discrete estimate of the most likely bacterial density, is certainly no more reliable than the experimental technic on which the evaluation is based. Furthermore, it is dependent on the validity and rationalism of the assumptions upon which application of the theoretical principles involved are predicted. As mentioned previously the assumption of randomness of the bacterial distribution may or may not apply for a particular case.

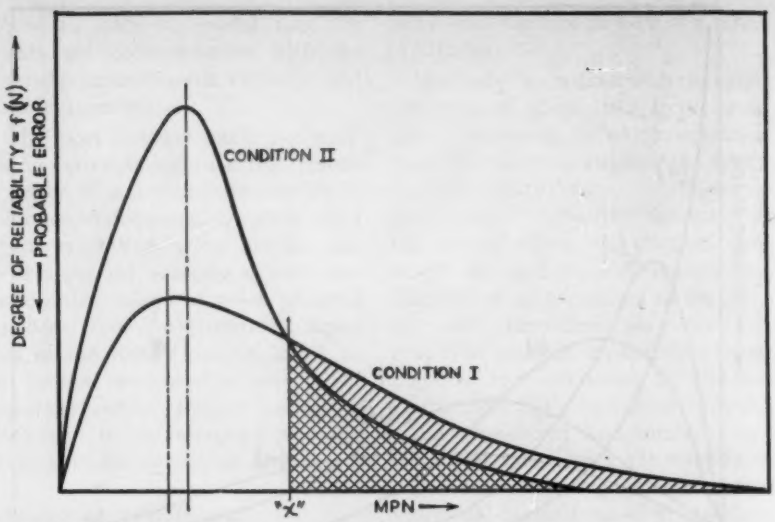


Fig. 2—FREQUENCY DISTRIBUTION: Multiple serial dilution (Condition I) vs. single dilution (Condition II), showing relative variability (probable error) where degree of pollution is apparently similar.

The validity of such an assumption, of course, cannot be accurately determined for any sample; however, its very intangibleness reflects on, or at least limits, the degree of confidence which can be attributed to the final result. It has been estimated, for example, that even when a sample contains one coliform per ml, about 37 per cent of all 1-ml portions examined would be expected to yield negative results[9]; and, if five 1-ml portions are examined, a completely negative result (that is 0/5) would be expected to occur in less than one out of 100 tests. Even so, the precision that can be expected cannot be considered of a high order.

The fermentation tube technic has an additional weakness attributable to the assumption (again reasonable, but unfortunately not always valid) that organisms of one variety exert no appreciable influence on the viability and growth of organisms of another (for example, in the case of coliform density examinations, cognizance is not taken of the effect of metabolic processes of non-coliforms or the action of predatory protozoa). The effect of this antibiosis phenomenon[1] can be minimized when, for a given sample volume, the size of inoculum is decreased and the number of portions is increased. Whether this tends to compensate, however, for the errors introduced when the portion size is small (for example, ten 10-ml portions vs one 100-ml portion*) is very doubtful.

In addition to deficiencies in actual laboratory technic involved, and personal errors associated therewith (some of which tend to be compensatory), the utility of fermentation tube test results is further limited by differences in the sensitivities of alternate permissible procedures; for example, brilliant green bile vs EMB agar in the confirmatory test for coliforms.† Experimental sources of variance, not only peculiar to the fermentation tube technic, do contribute, of course, to the precision of the results.

Each of these, not purported to represent the totality of factors bearing directly on the accuracy or precision of the MPN technic, does tend to limit the degree of reproducibility of the results which can be anticipated,

TABLE 3
Probable Limits of MPN When Five Fermentation Tubes Are Inoculated in a Single Dilution*

Case	No. of Positive Tubes	MPN per 100 ml
a	0/5	< 2.2
b	1/5	2.2
c	2/5	5.1
d	3/5	9.2
e	4/5	16.1
f	5/5	> 16.1

*From the U.S.P.H.S. "1946 Drinking Water Standards"[7].

* Often, pollution demonstrated in the examination of a 10-ml portion passes undetected in the examination of ten 10-ml portions identically tested.[4]

† There is evidence that these media do not differentiate precisely the identical group of bacteria, the bile medium usually producing a higher "coliform" recovery.[10]

especially under routine performance. Although this may be of little practical import in many instances, it is of especial significance where quantitative evaluations are indicated; as, for example, when the efficacy of two different technics is being compared, or in appraising the sanitary quality of milk, streams, shellfish-producing waters, etc. Such a distinction, of course, is of paramount importance, but too often it is disregarded.

Status of MPN Technic

Over the years it has become accepted that the coliform index constitutes a reasonably good and accurate measure of quantitative pollution. Of course, the method employed to obtain an accurate estimate of coliform concentration ideally should yield statistically reliable results, over a wide variety of samples with different physical, chemical and biological characteristics, in as short a time possible; it should be simple and practicable in terms of material, space, labor and interpretative skill required; and it should be sufficiently economical to permit regular and frequent application. Except for occasional objectors, fermentation tube tests (single or multiple dilutions) have been recognized as most nearly approaching the foregoing performance criteria. Indeed, many who should know otherwise treat of MPN's with an almost sacred reverence. The earlier discussion attests to the fallaciousness of this concept.

Today it is generally unrefuted that in routine checks of sanitary water quality, where the approximate value of the bacterial density is known or can be determined, the most effective technic is obtained by inoculating all tubes at a single dilution, the volume of the dilution and the number of tubes being chosen so that the probability of obtaining a proportion of positive tubes which will result in rejection of the supply will be small when the density is within the customary range; and very large when the bacterial density is outside this range. Further, when the approximate bacterial density is unknown, several tubes should be inoculated at each of a series (geometric, in ascending powers of 10).

Status of MF Technic

Although the principles and technics of membrane filtration cannot be considered the *ne plus ultra* in achievement, application of this control test in sanitary bacteriology can help to minimize the misconceptions and greatly reduce the elements of uncertainty of the MPN coliform index.

Pros and Cons

Some investigators have been unable to account for the disparity in coliform recovery between the MPN and the membrane filter technics. Although the significance of the difference between the biological populations identified by the two tests, if any, remains to be determined, much of the disparity in quantitative results can be attributed to bias inherent in the derivation of MPN's. Thus, the disparity is more apparent than real. In comparing the relative merits of the two technics, Thomas and Woodward[11] estimated that the precision obtained with a single filter is from two to five times greater than that of a 5-5-5 tube MPN.

Aside from statistical and probability considerations discussed previously, another weakness of the tube test method is the fact that it is so relatively laborious, complex and time-consuming that catholic application is largely prohibitive. The expenses involved in the mailing of samples, losses, breakage, etc., and in the laboratory examination itself, have considerably limited the areas for which bacteriological quality control is feasible.

Membrane filter investigators have demonstrated a substantial reduction in time, expense, material, equipment, and labor requirements. Moreover, when the test is properly employed, they have suggested the probability that errors in personal judgment are perceptibly minimized, and that the results surpass in certainty, accuracy, and duplicability, those that heretofore have been possible for tube tests applied within the obvious limits of practicability recognized by "Standard Methods."[9]

Summary

Twenty years ago Hoskins[4] asserted that ". . . it seems reasonable to conclude that the dilution tube method cannot result in an accurate enumeration of coli-aerogenes organisms and that, therefore, the need for an acceptable and dependable method still remains." He added further that ". . . if correspondingly as much study (as the MPN) were devoted to the development of a suitable plating phase of coli-aerogenes enumeration, it is quite reasonable to believe that this effort would yield a method superior to the present one."

The principal, often unrecognized, weaknesses and inherent limitations of the MPN index of coliform density which contributed to Hoskins[1] observation have been reviewed. Though MPN's have dubious value, especially on certain types of water, until the advent of the membrane filter technic they were recognized as most nearly approaching the ideal coliform index. Current indications are that the membrane filter technic more closely fulfills the desired requisites and that it represents a closer measure of the true coliform density of a sample.

It is anticipated that further refinements leading to routine utilization of the membrane filter as an in-place test to complement the sanitary survey will satisfy the exigent need for more frequent and representative hygienic control of the environment than has ever before been realized.

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Chart for Capacity of Rectangular Weirs

b = Length of Weir in Feet
Based on Francis Weir Formulae as follows
no end contractions Q = 3.33·b·h^3/2
with " " Q = 3.33(b - .2h) h^3/2 = 3.33·b·h^3/2 - .667h^5/2
Q = cubic feet per second b = length of weir in feet h = height of weir in feet
GPM to be subtracted from Flow for Contracted Weirs = .667h^5/2 × 450
Height of Weir in Inches
Flow in G.P.M.
Q = Flow over Weir in C.F.S.

NOMINAL DIAMETER OF PIPE IN INCHES
FORMULA FOR AIR FLOW

FORMULA FOR AIR FLOW

THIS CHART IS BASED ON THE FORMULA:

$$h_{100} = 3.86 \frac{f v^2}{d \rho}$$

WHICH IS A MODIFICATION OF THE WELL-KNOWN DARCY FORMULA FOR TURBULENT FLOW OF FLUIDS.

h_{100} = HEAD LOSS OR PRESSURE DROP PER 100 FT. OF PIPE, IN INCHES OF WATER.

f = HYDRAULIC FRICTION FACTOR DEPENDING ON REYNOLD'S NUMBER AND THE RELATIVE ROUGHNESS OF THE INSIDE BOUNDARY MATERIAL OF THE PIPE. VALUES WERE OBTAINED FROM "FRICTION FACTORS FOR PIPE FLOW" BY MOODY, TRANS. A.S.M.E., VOL. 66 NO. 8, 1944, PP. 671-684.

ρ = DENSITY OF AIR AT FLOW CONDITIONS, IN LBS. PER CU. FT.

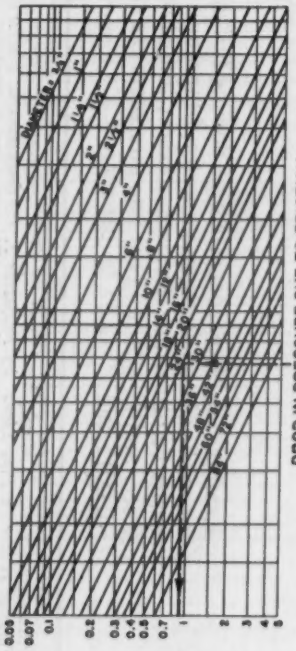
v = THE MEAN VELOCITY OF FLOW, IN FT. PER SEC.

d = INTERNAL DIAMETER OF PIPE, IN INCHES.

CORRECTION FACTORS

THE FOLLOWING TABLE CONTAINS MULTIPLIERS FOR APPROXIMATING THE "DROP IN PRESSURE DUE TO FRICTION" WHEN THE INSIDE PIPE SURFACE DIFFERS FROM THAT ON WHICH CHART IS BASED.

TYPE OF SURFACE	PIPE SIZES		
	1/4"-2 1/2"	3"-10"	36"-84"
WROUGHT IRON, STEEL	0.90-0.95	0.94-0.93	0.92-0.93
GALVANIZED IRON	1.00	1.02-1.03	1.04-1.03
CAST IRON (PLAIN)		1.15-1.18	1.16-1.18
CONCRETE (SMOOTH)			1.80-1.14
CONCRETE (ROUGH)			2.10-1.60
RIVETED STEEL (LIGHT)		1.70-1.40	1.80-1.60
RIVETED STEEL (HEAVY)		3.60-2.80	3.10-2.80
RANGE OF HEAD LOSS TO WHICH FACTORS APPLY	30"-0.1"	20"-0.1"	10"-0.1"



VELOCITY HEAD
INCHES OF WATER

NOMINAL DIAMETER OF PIPE IN INCHES

GALVANIZED PIPE—1/4 TO 2 1/2 INCHES

ASPHALTED CAST-IRON PIPE—3 TO 84 INCHES

DROP IN PRESSURE DUE TO FRICTION—INCHES OF WATER PER 100 FEET OF PIPE

CUBIC FEET OF FREE DRY AIR PER MINUTE
60° F., 29.92" MERCURY, 1 CU. FT. = 0.0764 LBS.

EXAMPLE:

RATE OF FREE AIR	14,000 C.F.M.
DIAMETER OF PIPE	24 INS.
MEAN TEMP. OF AIR IN PIPE	120° F.
MEAN GAGE PRESSURE	8 LBS. PER SQ. IN.
PRESSURE DROP PER 100 FT.	0.67 INS. OF WATER
VELOCITY HEAD	0.91 INS. OF WATER

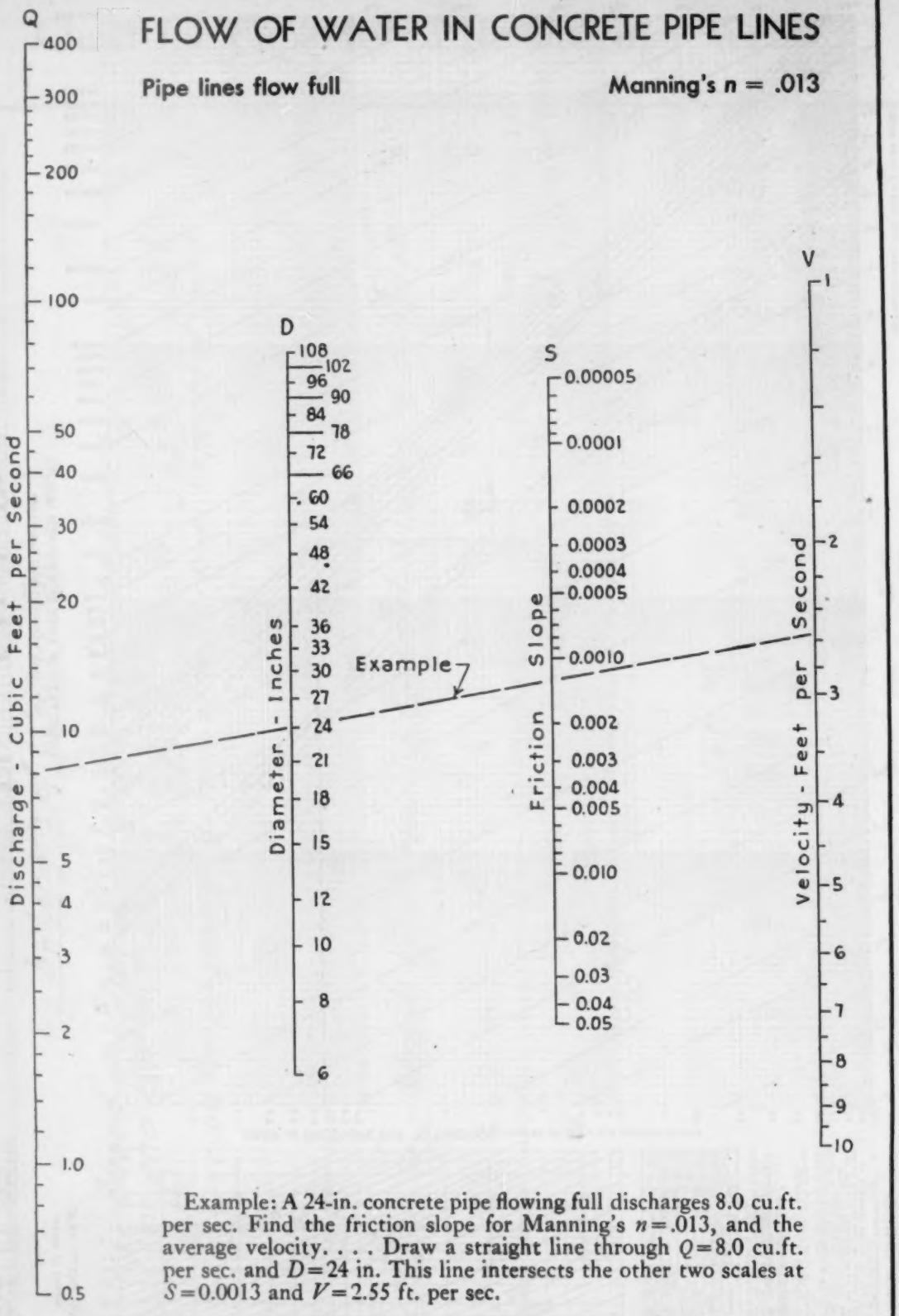
Flow of Air in Pipes

Courtesy of Chicago Pump Co.

FLOW OF WATER IN CONCRETE PIPE LINES

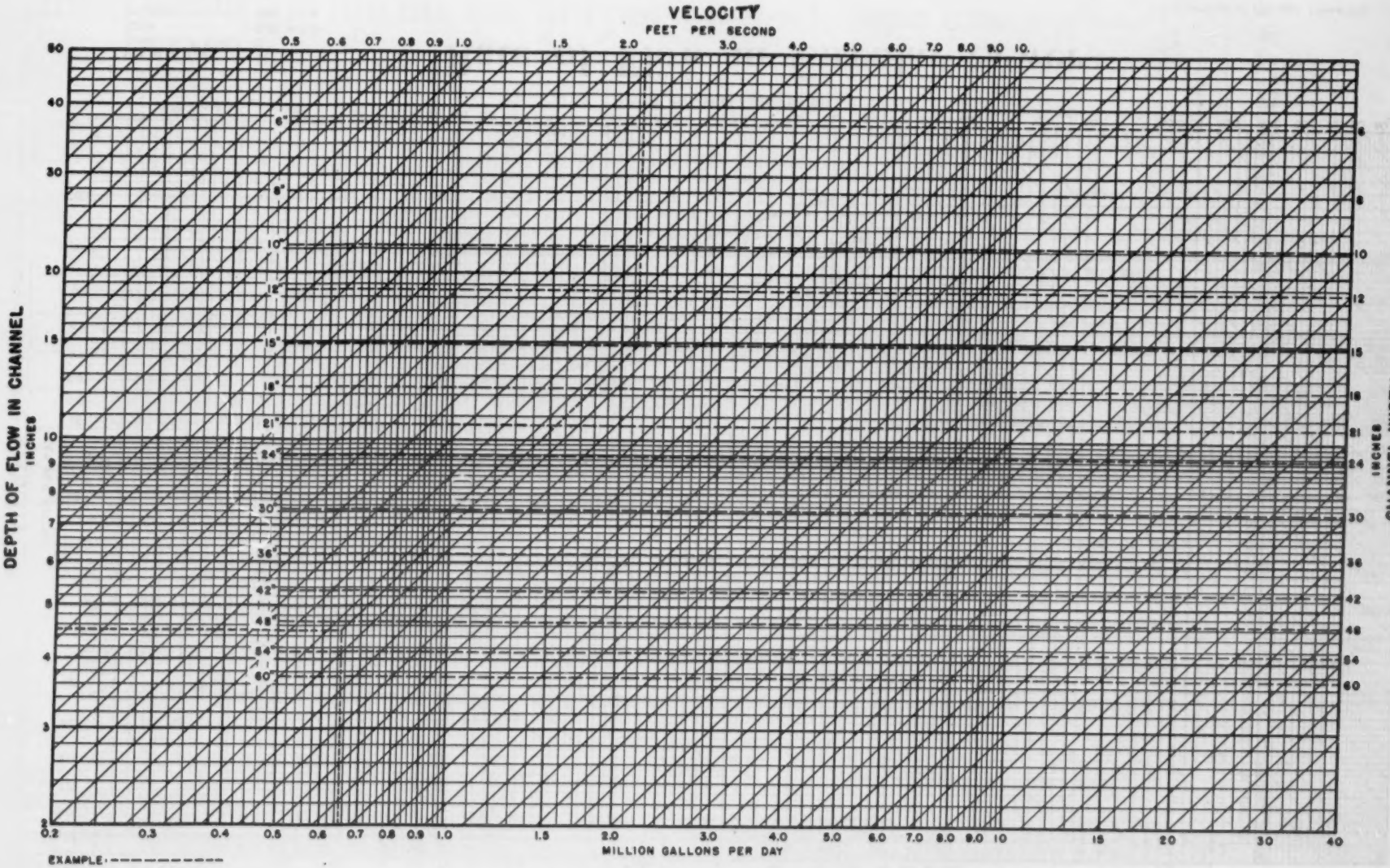
FLOWS THROUGH CONCRETE PIPE

Pipe lines flow full **Manning's n = .013**



Example: A 24-in. concrete pipe flowing full discharges 8.0 cu.ft. per sec. Find the friction slope for Manning's n=.013, and the average velocity. . . . Draw a straight line through Q=8.0 cu.ft. per sec. and D=24 in. This line intersects the other two scales at S=0.0013 and V=2.55 ft. per sec.

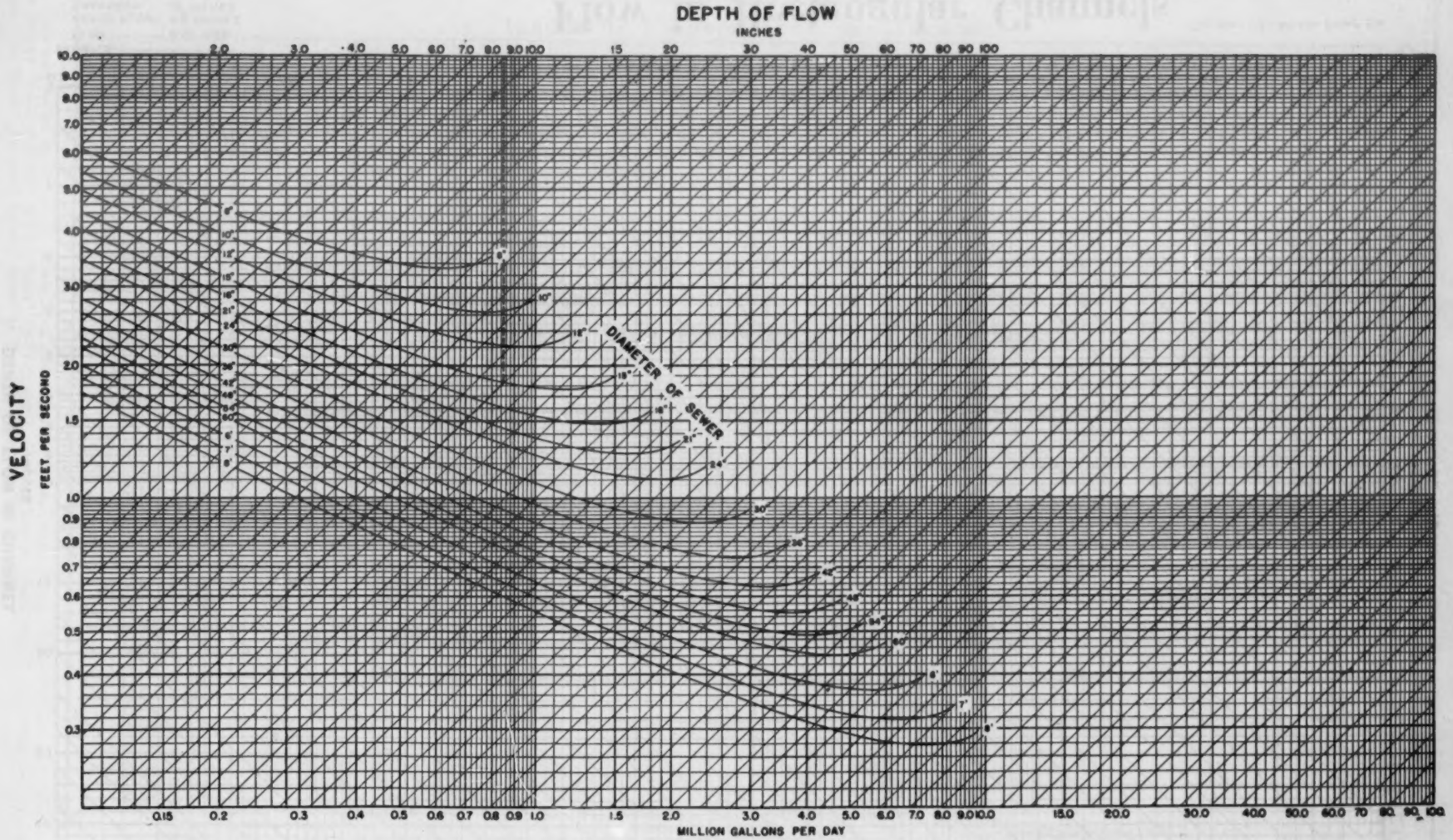
A chart constructed by Dr. F. T. Mavis, head Dept. of Civil Engineering, Penna. State College and appearing with the chapter "Flow of Water In Pipe Lines" by Professor J. E. Christiansen, University of California, written for "Concrete Pipe Lines," published by the American Concrete Pipe Association, 1942.



EXAMPLE:
FLOW - 0.65 M.G.D.
DEPTH FLOW - 4½ INCHES.
CHANNEL - 15 INCHES.
VELOCITY = 2.15 F.P.S.

Flow in Rectangular Channels

Courtesy of Chicago Pump Co.



Rate of Flow in Circular Sewers

Courtesy of Chicago Pump Co.

Friction of Water Pipes

The pipe frictions shown in the following tables are taken by permission from the more complete copyright tables by Williams and Hazen, published by John Wiley & Sons, and these values are recommended for use in figuring pipe frictions.

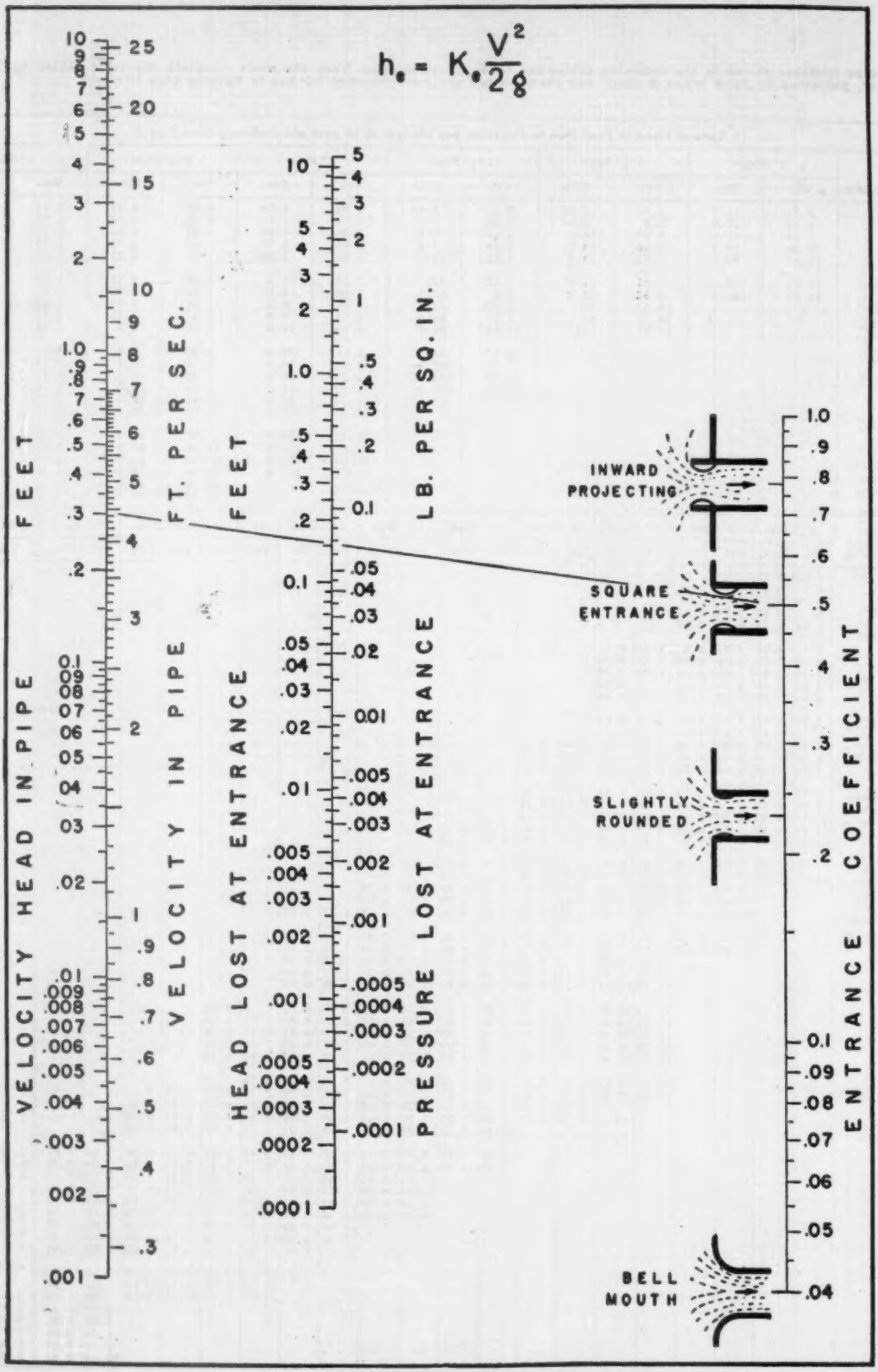
Loss of Head in Feet Due to Friction, per 100 feet of 15 year old Ordinary Iron Pipe

U.S. Gal's per Min.	1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
10	3.72	11.7	2.14	3.05	1.57	1.43	1.02	0.50	0.65	0.17	0.45	0.07
15	5.60	25.0	3.2	6.50	2.36	3.0	1.53	1.0	0.98	0.36	0.68	0.15
20	7.44	42.0	4.29	11.1	3.15	5.2	2.04	1.82	1.31	0.61	0.91	0.25
25	9.30	64.0	5.36	16.6	3.94	7.8	2.55	2.73	1.63	0.92	1.13	0.38
30	11.15	89.0	6.43	23.5	4.72	11.0	3.06	3.84	1.96	1.29	1.36	0.54
35	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.1	2.29	1.72	1.59	0.71
40	14.88	152.0	8.58	40.0	6.3	18.8	4.08	6.6	2.61	2.20	1.82	0.91
45			9.65	50	7.08	23.2	4.60	8.2	2.94	2.80	2.05	1.15
50			10.72	60	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38
70			15.01	113	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57
90					14.17	84.0	9.19	29.4	5.88	9.8	4.09	4.08
100					15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96
120					18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0
140					22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2
160							16.34	86.0	10.46	29.0	7.26	11.8
180							18.38	107.0	11.76	35.7	8.17	14.8
200							20.42	129.0	13.07	43.1	9.08	17.8
220							22.47	154.0	14.38	52.0	9.99	21.3
240							24.51	182.0	15.69	61.0	10.89	25.1
260							26.55	211.0	16.99	70.0	11.80	29.1
280									18.30	81.0	12.71	33.4
300									19.61	92.0	13.62	38.0

U. S. Gal's per Min.	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		15" Pipe		16" Pipe		20" Pipe		24" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
40	1.02	0.22																				
45	1.17	0.28																				
50	1.28	0.34																				
70	1.79	0.63	1.14	0.21																		
75	1.92	0.73	1.22	0.24																		
100	2.55	1.22	1.63	0.41	1.14	0.14																
120	3.06	1.71	1.96	0.58	1.42	0.25																
125	3.19	1.86	2.04	0.64	1.48	0.28																
150	3.84	2.55	2.45	0.88	1.71	0.32																
175	4.45	3.44	2.86	1.18	2.00	0.48																
200	5.11	4.40	3.27	1.48	2.28	0.62																
225	5.77	5.45	3.67	1.86	2.57	0.74																
250	6.40	6.72	4.08	2.24	2.80	0.92	1.60	0.22														
270	6.90	7.70	4.42	2.60	3.03	1.13	1.70	0.25														
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27														
300	7.66	9.38	4.90	3.14	3.40	1.29	1.90	0.32														
350	8.90	12.32	5.72	4.19	3.98	1.75	2.20	0.42														
400	10.21	16.00	6.54	5.40	4.54	2.21	2.60	0.54														
450	11.50	19.80	7.35	6.70	5.12	2.65	2.92	0.68	1.80	0.21												
470	12.10	22.40	7.70	7.22	5.49	2.90	3.07	0.75	1.92	0.24												
475	12.20	22.96	7.76	7.42	5.55	2.95	3.10	0.76	1.94	0.25												
500	12.77	24.00	8.17	8.12	5.60	3.30	3.20	0.82	2.04	0.28	1.42	0.11										
550			8.99	9.60	6.16	3.93	3.52	0.97	2.25	0.33	1.57	0.14										
600			9.80	11.30	6.72	4.70	3.84	1.14	2.46	0.39	1.71	0.15										
650			10.62	13.20	7.28	5.40	4.16	1.34	2.66	0.46	1.85	0.19	1.37	0.09								
700			11.44	15.10	7.84	6.20	4.46	1.54	2.86	0.52	2.00	0.22	1.47	0.10								
750			12.26	17.20	8.50	7.00	4.80	1.74	3.06	0.59	2.13	0.24	1.58	0.11								
800					9.08	8.00	5.12	1.97	3.28	0.67	2.27	0.27	1.68	0.13								
850					9.58	8.95	5.48	2.28	3.48	0.75	2.41	0.31	1.79	0.14								
900					10.30	10.11	5.75	2.46	3.68	0.83	2.56	0.34	1.89	0.16								
950					10.72	10.80	6.06	2.87	3.88	0.91	2.70	0.38	2.00	0.18	1.73	0.12						
1000					11.32	12.04	6.40	3.02	4.08	1.01	2.84	0.41	2.10	0.19	1.82	0.14						
1050					11.90	13.30	6.70	3.21	4.29	1.09	2.98	0.44	2.20	0.22	1.91	0.16						
1100					12.50	14.31	7.03	3.51	4.50	1.20	3.13	0.49	2.31	0.23	2.00	0.17						
1150					12.95	15.60	7.35	3.84	4.71	1.34	3.27	0.53	2.42	0.25	2.09	0.18						
1200					13.52	16.69	7.67	4.15	4.91	1.46	3.41	0.57	2.52	0.26	2.18	0.19						
1250					14.10	18.50	8.00	4.45	5.11	1.51	3.55	0.62	2.63	0.29	2.28	0.20	1.99	0.15				
1500							9.60	6.27	6.10	2.09	4.20	0.85	3.15	0.39	2.73	0.28	2.39	0.21				
2000							12.70	10.71	8.10	3.65	5.60	1.43	4.20	0.66	3.64	0.54	3.19	0.39			1.42	0.05
2500									10.10	5.33	7.00	2.28	5.25	1.01	4.55	0.72	3.99	0.56			1.77	0.07
3000									12.10	7.80	8.40	3.15	6.30	1.47	5.46	1.12	4.79	0.80	3.08	0.27	2.13	0.10
3500									14.10	10.08	9.80	4.10	7.35	1.81	6.37	1.43	5.59	1.04	3.59	0.35	2.49	0.14
4000											11.35	5.32	8.40	2.47	7.28	1.85	6.38	1.34	4.10	0.45	2.85	0.18
4200											11.93	6.00	8.82	2.80	7.64	2.08	6.72	1.45	4.32	0.50		
4500											12.78	6.90	9.45	3.22	8.19	2.23	7.20	1.65	4.62	0.56	3.20	0.22
5000											14.20	8.40	10.50	3.92	9.10	2.78	7.96	2.02	5.13	0.68	3.54	0.27
5500													11.55	4.65	10.01	3.30	8.78	2.39	5.64	0.82	3.90	0.33
6000													12.60	5.50	10.92	3.90	9.56	2.60	6.15	0.96	4.25	0.38
6500													13.65	6.45	11.83	4.55	10.36	3.32	6.66	1.06	4.61	0.45
7000													14.70	7.15	12.74	5.08	11.12	3.68	7.18	1.28	4.97	0.52
7200															13.10	5.45	11.50	3.96	7.38	1.35		
7500															13.65	5.90	11.95	4.28	7.66	1.45	5.32	0.59
8000																			8.17	1.63	5.68	0.66
8500																			8.68	1.83	6.03	0.74
9000																			9.20	2.04	6.35	0.81
9500																			9.70	2.23	6.74	0.91
10000																			10.40	2.53	7.07	0.98

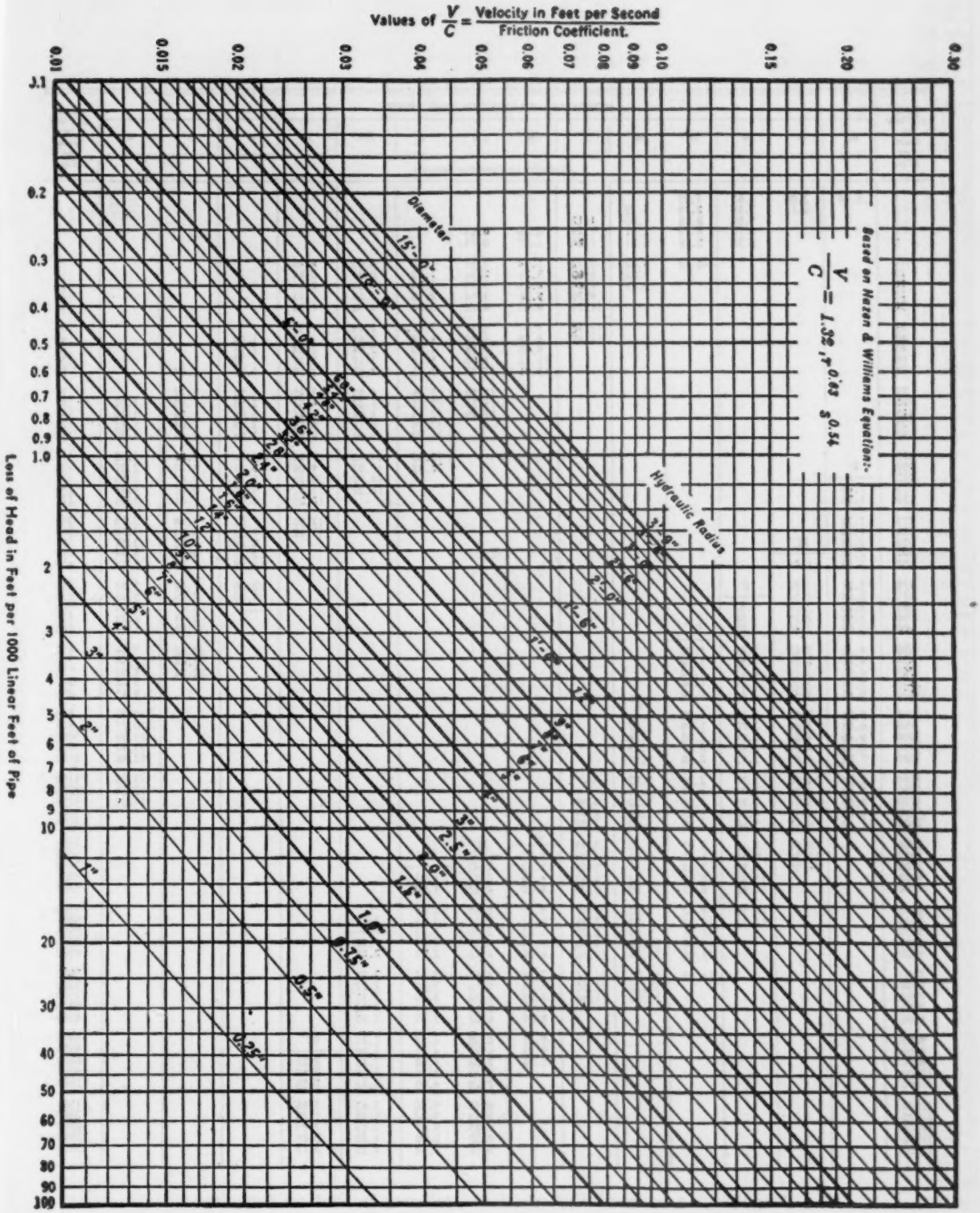
Vel.—Velocity ft. per second. Fric.—Friction head in feet.

Hydraulic Entrance Losses



Courtesy of J. R. Griffith, U. S. Navy, and Western Construction News

Loss of Head in Feet Per 1000 Ft. of Pipe



From "Hydro-Electric Handbook"—John Wiley & Sons

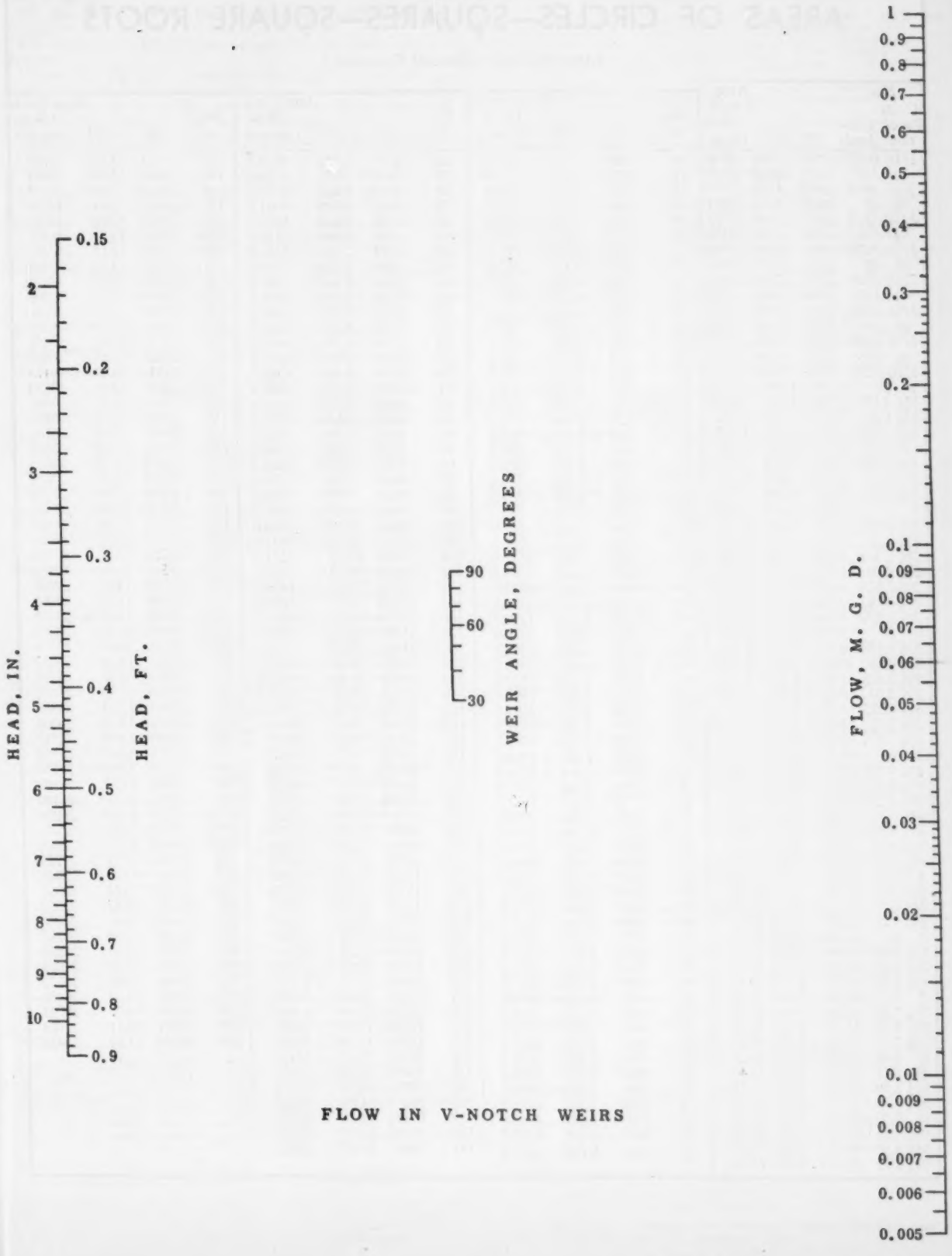
Velocity In Pipes

Rate of Flow in Gals. per Min.	NOMINAL DIAMETER OF PIPE (Velocity in Feet Per Second)														Rate of Flow in Gals. per Min.
	⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	
1	5.60	3.08	1.67	1.05											1
2		6.16	3.35	2.10	1.20										2
3			5.02	3.16	1.80	1.12									3
4			6.70	4.21	2.41	1.49	0.86	0.63							4
5			8.37	5.26	3.01	1.86	1.07	0.79							5
10				10.52	6.02	3.72	2.14	1.57	1.02	0.65	0.45				10
15					9.02	5.60	3.21	2.36	1.53	0.98	0.68				15
20					12.03	7.44	4.29	3.15	2.04	1.31	0.91				20
25						9.30	5.36	3.94	2.55	1.63	1.13				25
30						11.15	6.43	4.72	3.06	1.96	1.36				30
35						13.02	7.51	5.51	3.57	2.29	1.58				35
40						14.88	8.58	6.30	4.08	2.61	1.82	1.02			40
45							9.65	7.08	4.60	2.94	2.04	1.15			45
50							10.72	7.87	5.11	3.27	2.27	1.28			50
70							15.01	11.02	7.15	4.58	3.18	1.79	1.14		70
75								11.80	7.66	4.90	3.40	1.92	1.22		75
100								15.74	10.21	6.54	4.54	2.55	1.63	1.10	100
120								18.89	12.25	7.84	5.45	3.06	1.96	1.36	120
125									12.75	8.16	5.66	3.19	2.04	1.42	125
150									15.32	9.80	6.80	3.84	2.45	1.70	150
175									17.85	11.40	7.94	4.46	2.86	1.98	175
200									20.42	13.07	9.08	5.11	3.27	2.27	200
225	8"									14.70	10.20	5.75	3.67	2.55	225
250	1.60									16.30	11.32	6.38	4.08	2.84	250
270	1.73										12.25	6.90	4.41	3.06	270
275	1.76										12.50	7.03	4.49	3.12	275
300	1.92										13.62	7.66	4.90	3.40	300
350	2.24	10"										8.94	5.72	3.98	350
400	2.56											10.21	6.54	4.54	400
450	2.88	1.84										11.49	7.35	5.11	450
470	3.01	1.92	12"									12.00	7.68	5.34	470
475	3.04	1.94										12.10	7.75	5.40	475
500	3.20	2.04	1.42									12.77	8.17	5.68	500
550	3.52	2.25	1.56		14"								8.99	6.24	550
600	3.84	2.45	1.70										9.80	6.81	600
650	4.16	2.65	1.85	1.30									10.62	7.38	650
700	4.48	2.86	1.99	1.40									11.44	7.94	700
750	4.80	3.06	2.13	1.50									12.26	8.50	750
800	5.12	3.27	2.27	1.60										9.08	800
850	5.45	3.47	2.41	1.70										9.65	850
900	5.76	3.67	2.56	1.80	15"									10.20	900
950	6.08	3.88	2.70	1.90	1.67									10.77	950
1000	6.40	4.08	2.84	2.00	1.76									11.34	1000
1050	6.72	4.29	2.98	2.10	1.85									11.90	1050
1100	7.04	4.49	3.13	2.20	1.93									12.48	1100
1150	7.36	4.70	3.27	2.30	2.02	16"								13.05	1150
1200	7.68	4.90	3.41	2.40	2.11									13.61	1200
1250	8.00	5.41	3.55	2.50	2.20	1.99								14.20	1250
1500	9.60	6.12	4.26	3.05	2.64	2.09									1500
2000	12.80	8.10	5.68	4.00	3.52	3.09									2000
2500		10.20	7.10	5.01	4.40	3.98	20"								2500
3000		12.24	8.52	6.01	5.28	4.78	3.07	24"							3000
3500		14.50	9.95	7.02	6.16	5.58	3.53	2.43	30"						3500
4000			11.36	8.02	7.04	6.33	4.10	2.83	1.81						4000
4200			11.92	8.42	7.40	6.70	4.30	2.97	1.90						4200
4500			12.78	9.02	7.92	7.17	4.61	3.19	2.04						4500
5000			14.20	10.02	8.80	7.96	5.12	3.54	2.26	36"					5000
5500				11.01	9.69	8.77	5.63	3.90	2.49						5500
6000				12.00	10.56	9.56	6.14	4.25	2.72	1.57					6000
6500				13.00	11.44	10.36	6.66	4.60	2.94	2.05					6500
7000				14.02	12.32	11.16	7.16	4.97	3.17	2.21					7000
7200					13.20	11.50	7.38	5.16	3.26	2.27					7200
7500					14.00	11.96	7.69	5.32	3.40	2.37					7500
8000							8.20	5.66	3.62	2.52					8000
8500							8.70	6.02	3.85	2.68					8500
9000							9.21	6.38	4.08	2.84	42"				9000
9500							9.72	6.72	4.31	3.00					9500
10000							10.24	7.08	4.58	3.15	2.31				10000
10500								7.44	4.76	3.30	2.43				10500
11000								7.79	4.99	3.46	2.55				11000
11500								8.15	5.28	3.62	2.66				11500
12000								8.50	5.44	3.78	2.78				12000
12500								8.85	5.67	3.93	2.89				12500
13000								9.20	5.90	4.08	3.01				13000
13500								9.56	6.12	4.25	3.13				13500

This table is taken from "Hydraulic Data," published by Gould's Pumps, Inc.

FLOW IN V-NOTCH WEIRS

by L. E. Livingston, Jr.
Wichita, Kansas



FLOW IN V-NOTCH WEIRS

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
⅛	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
¼	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
⅜	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
½	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
⅝	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
¾	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
⅞	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1⅛	1.125	1.266	1.061	.9940
1¼	1.25	1.563	1.118	1.227
1⅜	1.375	1.891	1.175	1.485
1½	1.50	2.250	1.225	1.767
1⅝	1.625	2.641	1.275	2.074
1¾	1.75	3.063	1.323	2.405
1⅞	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2⅛	2.125	4.516	1.458	3.547
2¼	2.25	5.063	1.500	3.976
2⅜	2.375	5.641	1.541	4.430
2½	2.50	6.250	1.581	4.909
2⅝	2.625	6.891	1.620	5.412
2¾	2.75	7.563	1.658	5.940
2⅞	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3⅛	3.125	9.766	1.768	7.670
3¼	3.25	10.56	1.803	8.296
3⅜	3.375	11.39	1.837	8.946
3½	3.50	12.25	1.871	9.621
3⅝	3.625	13.14	1.904	10.32
3¾	3.75	14.06	1.937	11.04
3⅞	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4⅛	4.125	17.02	2.031	13.36
4¼	4.25	18.06	2.062	14.19
4⅜	4.375	19.14	2.092	15.03
4½	4.50	20.25	2.121	15.90
4⅝	4.625	21.39	2.151	16.80
4¾	4.73	22.56	2.180	17.72
4⅞	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5¼	5.25	27.56	2.291	21.65
5½	5.50	30.25	2.345	23.76
5¾	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6¼	6.25	39.06	2.500	30.68
6½	6.50	42.25	2.550	33.18
6¾	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7¼	7.25	52.56	2.693	41.28
7½	7.50	56.25	2.739	44.18
7¾	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8¼	8.25	68.06	2.872	53.46
8½	8.50	72.25	2.916	56.75
8¾	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9¼	9.25	85.56	3.041	67.20
9½	9.50	90.25	3.082	70.88
9¾	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16513
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
...	.....	....	.....
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Conversion Factors

The word gallon, used in any conversion factor, designates the U.S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2} 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U.S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4,047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" " "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Gains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., Stamford, Conn.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" " "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T. Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

$$\text{Conversion of °C to °F or °F to °C} = \frac{C}{100} = \frac{F - 32}{180}$$

Weights and Measures

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound
Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound
The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)
27 11/32 grams = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs = 1 short ton
2,240 lbs = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
1 British bushel = 1.032 U.S. bushel
8 quarts = 1 peck
4 pecks = 1 bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead
1 British Imperial gallon = 1.200 U.S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cp. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9,2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains

Oxygen In Water

Solubility and Percentage Saturation

A previous nomograph for the solubility of atmospheric oxygen in water is herewith modified by well-known methods to yield, in addition, percentage saturation. The new chart provides solution of Hatfield's equation (Sew. Wks. Jou. 73:557—1941)

$$S = \frac{0.678\ (P - \mu)}{t + 35}$$

and the equation $x = 100\ \sigma / S$

where S = solubility of oxygen, ppm
P = barometric pressure, mm of mercury
μ = vapor pressure of water at t° C
σ = oxygen dissolved in sample, ppm
x = percentage saturation

The upper index line connects 764 mm on the P-scale with 18° on the t-scale and shows on the S-scale that the solubility of oxygen in water under these conditions is 9.6 ppm. The lower index line connects 9.6 on the S-scale with 6.0 on the σ-scale and shows on the x-scale that the water is 63 per cent saturated with oxygen.

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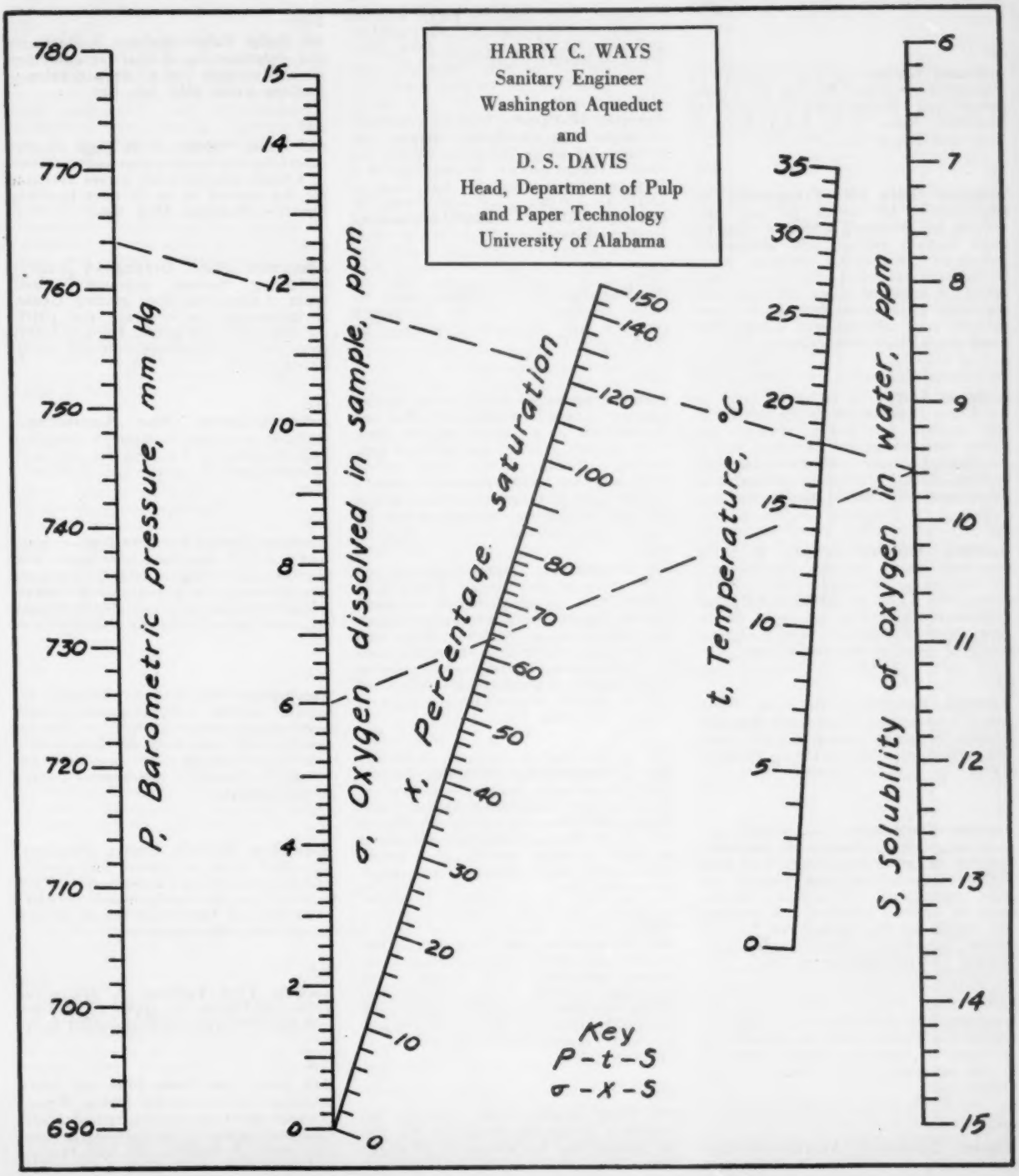

BULLETINS and CATALOGS

For Copies of any of the Bulletins or Catalogs Listed Below, Circle the Corresponding Numbers on the Inquiry Reply Card in this Section.

1*R*
Acid Handling Pump—This catalog briefly describes the design features, operation and application of this positive displacement metering pump for sulfuric acid in concentrations up to 66° Baumé.—Precision Chemical Pump Corp.

2*R*
Activated Nuchar—12 page booklet on Powdered Activated Nuchar for Purification and Reclamation.—Industrial Chemical Sales Div., West Virginia Pulp and Paper Co.

3*R*
Activated Silica Sols Preparation—Series Sheet "A" covers jar test procedures for preparing activated silica sol from sodium silicate and ammonium sulfate as the reacting chemical. Sheet "B" details procedures for batch preparation of activated silica sol with such reactants as ammonium sulfate, alum, chlorine etc. Illustrations show flow diagrams.—Philadelphia Quartz Co.

4*R*
Activated Sludge—A technical study on the Kraus Process covers the dual aeration system for power savings and sludge interchange for beneficial use of supernatant liquor and elimination of bulking. Actual plant data. Design considerations.—Pacific Flush Tank Co.

5*R*
Aeration Blowers—Bulletin RAS-158 describes rotary positive displacement air blowers in 38 standard sizes, rated from 2800 CFM to 10,000 CFM, and suitable for pressures up to 10 PSIG. New vertical compact design is featured.—Roots-Connersville Blower

6*R*
Aeration Equipment—Bulletins 175-A and 177 cover the Wide-Band Aeration System, featuring swing diffuser units and precision diffuser tubes.—Chicago Pump Co.

7*R*
Aeration Equipment—This booklet presents complete information on the development, design and application of both Walker Diffusair and Impingement aeration equipment. It includes discussions on channel aeration, grit aeration and details on the Walker Air Lift for return activated sludge pumping.—Walker Process Equipment Inc.

8*R*
Aerator—Bulletin Number 7316 describes the development, design and advantages for supplying oxygen demands in the activated sludge process.—Dorr Oliver Inc.

9*R*
Aerator Cavitator® Aerators—twelve-page catalog describes this different type of surface aerator for treatment of domestic and industrial wastes by either aerobic digestion or activated sludge process.—Yeomans Brothers Company.

10*R*
Aerators—This bulletin gives a brief outline of equipment for the aeration and removal of gases and odor from water.—General Filter Co.

11*R*
Aerators Hi-Cone®—The high intensity, high capacity surface aerator for sewage and waste treatment by the activated sludge process is described in a 12-page catalog. Available for plants as small as 100,000 g.p.d.—no limits on maximum flows handled.—Yeomans Brothers Company.

12*R*
Aer-Degritter—This brochure gives detailed information on the company's Aerated Grit Removal System.—Chicago Pump Co.

13*R*
Aero-Accelerator®—Activated Sludge plants combine biological oxidation and clarification in a single compact unit. They provide efficient operation at high loadings, stability under shock conditions and low installation cost, can be designed for complete treatment. Bulletin 6510-D—Infilco Incorporated

14*R*
Air Compressor, Tractor-type—Catalog 5740 presents the Heavy PNEUMATRACTOR, a self-propelled air compressor capable of mounting major accessories such as backhoe, front end loader, dozer blade and other construction equipment. Available with gas or diesel engine. Furnishes 125 cfm at 100 psi to operate accessories or separate tools.—Schramm, Inc.

15*R*
Air Compressors, Portable—Bulletin SPB-58 presents a complete line of Portable Air Compressors, gasoline and diesel, with capacities from 20 cfm to 600 cfm at 100 psi. Choice of skid, wheel or truck mounted models. Tool boxes, hose reels and other accessories.—Schramm, Inc.

16*R*
Air Compressors, Self-Propelled—Catalog 5945 describes self-propelled air compressor furnishing 125 or 250 cfm at 100 psi. Easy mobility of these units plus ability to mount accessories makes them especially adaptable for both operational and maintenance applications.—Schramm, Inc.

17*R*
Air Filter System—This brochure describes in detail the company's Air Filter System for Air Diffusion.—Chicago Pump Co.

18*R*
Air Lift Pump—Bulletin describes this low lift pump as simple and less costly to maintain than centrifugal pumps on lifts of 3 to 6 ft.—Walker Process Equipment, Inc.

19*R*
Air Relief Valve—Bulletin F illustrates and describes the Rensselaer combined air and vacuum and air release valve.—Ludlow Valve Mfg. Co., Inc.

20*R*
Air Relief Valves—A 28 page booklet describing the construction and operation of Crispin automatic air valves available for the control of air in lines handling liquids.—Multiplex Mfg. Co.

21*R*
Aluminum Floor Grating—A bulletin discussing riveted, pressure locked, types of aluminum floor grating. General instruction for ordering and charts on safe loads are given. Borden Safety steps are also discussed.—Borden Metal Products Co.

22*R*
Asbestos-Cement Pipe Accessories—Bulletin describes company's complete line of products designed for use with asbestos-cement pipe.—Smith-Blair, Inc.

23*R*
Asbestos-Cement Pressure Pipe—4 page folder AP-17 describes advantages and features of asbestos-cement pressure pipe stressing the importance of "clear, full-flowing water—a community's most important asset".—Keasbey & Mattison Co.

24*R*
Automation—This bulletin discusses automatic control of filter operation with interlocking safety devices to prevent overflow of clearwell or dangerously low filter levels. It presents the "C.-A.-P. System" instruments.—Infilco Incorporated.

25*R*
Back Hoes, Shovels, Cranes, Draglines, etc.—Full series of feature and specification literature on complete Series 350 product line. Carrier-mounted, crawler-mounted and self-propelled models.—Schield Bantam Company

26*R*
Bacteria Free Packing—A descriptive leaflet on Fibrex, an approved sanitary packing.—Hydraulic Development Corp.

27*R*
Ball Joint Cast Iron Pipe for River Crossing and submarine piping. 8-page brochure gives description, specifications data, and assembly instructions for this pipe with 15 degrees full free turning deflection.—James B. Clow & Sons, Inc.

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28*R*

Ball & Socket Cast Iron Pipe—This bulletin describes the Clow ball & socket cast iron pipe for river crossings and other uses where full 15-degree turning deflection is required.—James B. Clow & Sons, Inc.

29*R*

Bar Screens—These two bulletins discuss and illustrate Rex Heavy-Duty Bar Screens and front-cleaned bar screens.—Chain Belt Co.

30*R*

Barminutor—Bulletin 185-0 illustrates and describes advantages, principles of operation, applications, mechanical descriptions, detailed specifications and other information on the company's Barminutor comminuting machines for use in rectangular channels.—Chicago Pump Co.

31*R*

Bascule Gate—This bulletin provides dimensions, description and typical installations of this crest gate for pond level and flood control.—Allis-Chalmers Mfg. Co.

32*R*

Bell-Tite Joint Cast Iron Pipe—Bulletin describes this single gasket, compression type cast iron pipe joint for water and sewerage under pressure.—James B. Clow & Sons, Inc.

33*R*

Blowers—Bulletins S59-G and S65-C cover rotary positive displacement blowers for air and gas compressing, featuring oil free metered air delivery up to 10 pounds gauge pressure, single stage. —Sutorbilt Corp.

34*R*

Boxes, Valve, Service, Roadway and Meter—Bulletins and Catalogs describing sizes and types of standard Buffalo and special types.—Opelika Foundry Co., Inc.

35*R*

Carbonation—A handbook on carbonation of lime softened waters. Includes discussion of the background, chemical reactions, methods and problems in carbonation. Corrosion, due to impurities in CO_2 produced by certain methods, is thoroughly covered with tables giving corrosion resistance of various metals.—Walker Process Equipment, Inc.

36*R*

Cast Iron Pipe—Complete line of Cast Iron Pressure Pipe in sizes of 3 to 24 inches diameter is listed in catalog 54. Complete specifications and construction details.—Alabama Pipe Co.

37*R*

Cast Iron Pipe—This illustrated booklet provides pictorial proof of the ruggedness and durability of cast iron pipe in water supply and distributions; sewer mains; and industrial service.—Cast Iron Pipe Research Assn.

38*R*

Cast Iron Pipe—Catalog gives full details of weights and dimensions of "Sand-Spun" centrifugal cast iron pipe, cast iron fittings and specialties. Can be supplied with bell & spigot, mechanical joint or Tyton Joint.—R. D. Wood Co.

39*R*

Cathodic Protection—A series of three bulletins on cathodic protection: "Fighting Corrosion with Corrosion", "Cath-O-Chem System", and "Cathodic Protection for Water Works Plants."—Electro Rust-Proofing Corp.

40*R*

Cement Pipe Lining—A catalog describing the Centriline Process for pipes 4" to 144" including information on the new Centriline machine for placing a continuous cement mortar lining inside of all types of pipe in place. Bulletin includes illustrations of cleaning and lining equipment, hydraulic data and sample specifications for doing the work.—Centriline Corp.

41*R*

Centrifugal Pumps—This 20-page bulletin describes monobloc, single and two stage, centrifugal pumps in sizes ¾ to 6 inches. Drawings and rating curves are also included.—Worthington Corp.

42*R*

Ceramic Glazed Facing Tile—General Catalog S-59 gives many details and illustrations of the variable uses of Natco Ceramic Glazed Vitritile. This completely sanitary and low maintenance facing tile is suitable for all types of interior walls.—Natco Corp.

43*R*

Chemical Feeders—This catalog pictures and describes electric vibrating feeders for the feeding of dry chemicals in water and sewage treatment plants.—Jeffrey Mfg. Co.

44*R*

Chemical Feeders—Bulletin 30-H12A on gravimetric loss-in-weight feeders; Bulletin 35-G5A on belt gravimetric feeders; Bulletins 50.20-1 and 50-K57A on volumetric feeders; all for adding chemicals for water or waste-treatment.—Omega Machine Co.

45*R*

Chemical Feeders—Bulletin (3156) describes dry chemical feeders for the feeding of coagulants and other chemicals to Precipitators, detention tanks, etc. These feeders are of the volumetric displacement type—Permutit Co.

46*R*

Chemical Feeders—This bulletin describes positive displacement pumps for feeding corrosive fluids. Bulletin 1106-7 —Proportioners, Inc.

47*R*

Chemical Feeders—Publ. No. TP. 39M-5 describes volumetric dry feeders.—Wallace & Tiernan Inc.

48*R*

Chemical Pump—This catalog briefly describes the design features, operation and application of this positive displacement metering pump for chemical solutions.—Precision Chemical Pump Corp.

49*R*

Chemical Treatment—Bulletin A-705 discusses the use of chemicals in water and sewage treatment.—Columbia-Southern Chemical Div., Pittsburgh Plate Glass Co.

50*R*

Chemistry of Water—Bulletin 1237 describes the general character of chemical or mineral analysis of water, the meaning of the results and basic methods of water treatment for mineral removal.—Edward E. Johnson, Inc.

51*R*

Chlorine—General information, prices, list of local distributors, shipping containers on liquid chlorine, calcium hypochlorite, and sodium hypochlorite.—John Wiley Jones Co.

52*R*

Chlorine—A bulletin describing the physical properties, handling methods, uses and containers.—Pennsalt Chemicals Corp. Pa.

53*R*

Chlorine Dioxide—A booklet discussing in detail the removal of tastes and odors by chlorine dioxide treatment and its bactericidal properties, methods of treatment and application. Economic factors and general installation instructions are also included.—Chemicals Div., Olin Mathieson Chemical Corp.

54*R*

Chlorine Feeders—A series of bulletins on Chlorinizers, for feeding chlorine gas and other gases like ammonia, sulfur dioxide, etc. Capacities from 4 to 8000 lbs. per 24 hours. Bulletins 840-J8A and 840.20-1—Builders-Providence, Inc.

55*R*

Chlorine Feeders—A series of catalogs on chlorinators and accessory equipment, ranging in application from swimming pools to high capacity industrial requirements.—Fischer & Porter Co.

56*R*

Chlorine Feeders—Cat. File Nos. 20.100 50.110, present mechanical diaphragm vacuum type solution feeder and chlorine flow recorder.—Wallace & Tiernan Inc.

57*R*

Chlorine Feeders—Bulletins are available on V-Notch variable orifice chlorinators.—Wallace & Tiernan Inc.

58*R*

Chlorine Hand Book—76 pages, hard cover-describes equipment for handling chlorine, including shipping containers, safety and first aid measures. Also covers preparation of lime and sodium bleaches and analytical data on hypochlorites. Bulletin No. 125—Hooker Chemical Corp.

59*R*

Chlorine Handling—Bulletin A-505 discusses the problem of the Safe Handling of Chlorine.—Columbia-Southern Chemical Div., Pittsburgh Plate Glass Co.

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60*R*

Chlorine Residual Recorder—Catalog 50.250 describes the WT Residual Chlorine Recorder as an instrument for measuring residual chlorine amperometrically in a continuous sample and recording the reading in parts per million on a 24 hour circular chart. Advantages, case histories, design features, operation and technical data are included.—Wallace & Tiernan Inc.

61*R*

Chlorine—Safe Handling Practices (No. C-4012). Bulletin outlines methods for employee protection, leak detection and handling, personal protective devices, emergency measures, first aid treatment. Pennsalt of Washington Division, Pennsalt Chemicals Corp., Tacoma, Wash.

62*R*

Chlorine Wall Chart—This chlorine wall chart lists some of the important things to do in handling liquid chlorine in cylinders, ton containers and tank cars. It covers first aid and emergency procedures. The chart is clearly illustrated with diagrams of chlorine container valves. Bull. 132—Hooker Chemical Corp.

63*R*

Chlorine Wall Chart—Chart describes container valves, leak detection, first aid and accident procedures.—Pennsalt Chemicals Corp., Pa.

64*R*

Clarification—Bulletin #5811 illustrates and describes the five basic "Contraflo" designs and their application in water and waste treatment plants.—General Filter Co.

65*R*

Clarifier—This bulletin describes the design features and advantages of this new final unit for continuous, rapid sludge removal. Bulletin No. 6193 also includes installation photographs and line drawings of the unit, and a chart of design data.—Dorr Oliver Inc.

66*R*

Clarifier and Softener—Technical Reprint T-135 discusses the design of water clarifiers and softeners and presents details on the considerations that must be studied in designing a unit that is properly sized to handle the present and future load requirements—Graver Water Conditioning Co.

67*R*

Clarifiers—Verti-Flo clarifier tanks are covered in two bulletins. Efficient, low cost Verti-Flo is designed to clarify plant water, reclaim process water, eliminate pollution, or reclaim valuable materials.—Chain Belt Co.

68*R*

Clarifiers—Bulletin #6192 describes design features and advantages of Dorr mechanisms for circular and square settling basins. Photos and elevation drawings of units 30′ to 200′ in diameter are included in 16 pages.—Dorr-Oliver Inc.

69*R*

Clarifiers—Eimco-Process **Flotator-clarifier** removes low specific gravity solids by a combination of dissolved air flotation and conventional sedimentation in a single tank. Bulletin SM-1008—The Eimco Corp.

70*R*

Clarifiers—This bulletin 35-D describes two settling type clarifiers for both circular and rectangular tanks, equipped with both skimming and sludge scraping mechanisms.—Hardinge Company, Incorporated.

71*R*

Clarifiers Center Drive Clarifiers—Two types are detailed in Catalog 6502. Type "CD" is for tanks up to 50 ft. in diameter, the "CDH" for larger tanks.—Yeomans Bros. Company.

72*R*

Clarifiers—Spiraflo—Eight-page catalog details unique design which eliminates underground piping, concrete effluent troughs and mechanical skimmers.—Yeomans Brothers Company.

73*R*

Clariflocculator—This bulletin describes the physical characteristics, principle of operation, types, sizes and advantages of this combination flocculation and clarification mechanism. Included are photographs of operating installations and line and wash drawings of standard units.—Dorr-Oliver Inc.

74*R*

Clariflow—Bulletin 6W46 describes clariflow unit, a vertical rise clarification unit for circular, square and rectangular tanks.—Walker Process Equip. Inc.

75*R*

Coagulant Aids—Nomograph—"N-Sol" Process Coagulant aid preparation nomograph in chart form suitable for posting. Used to determine sodium silicate requirements, quantity of reacting chemical, necessary dilutions, expected alkalinity and preparations and feed rate for flow variations. All popular reacting chemicals listed.—Philadelphia Quartz Company.

76*R*

Coagulants—Technical Reprint T-138 discusses the selection of coagulants and chemical treatment for softening and coagulation in high-rate units. This article presents the different types of chemicals used, their properties and the proper method of testing each.—Graver Water Conditioning Co.

77*R*

Coal and Ash Handling—Two folders and a catalog on coal and ash handling layouts; also a catalog on chains, and a series of questions and answers on ash handling.—Beaumont-Birch Co.

78*R*

Coating, Coal Tar Epoxy—New bulletin describes Amercoat No. 78, a thermosetting coal tar epoxy coating to protect steel and concrete against fresh and sea water. Adhesion is not critical and the finished 8-mil film is tough and flexible.—Amercoat Corporation.

79*R*

Coating, Protective—A 4-page bulletin on Rexon coating no. 2 for protecting concrete pipe inside and out, from corrosive attack—Hamilton Kent Mfg. Co.

80*R*

Coating, Protective—This bulletin discusses use of Parlon Coatings on municipal and industrial plants.—Hercules Powder Co.

81*R*

Coatings, Coal Tar Epoxy—An 8-page laboratory report on four leading coal tar epoxy coatings compares their performance in 17 difficult tests. Establishes relative resistance to corrosion. Profusely illustrated.—Amercoat Corporation.

82*R*

Coatings, Masonry—This bulletin discusses the use of Parlon Chlorinated Rubber Masonry Paints for concrete, brick, cinder block, stucco and asphalt shingles—Hercules Powder Co.

83*R*

Coatings, Protective—This bulletin discusses and illustrates Dimecote #3, the 100% inorganic zinc silicate coating that provides near-permanent protection to steel exposed to severe conditions of rust, weathering and salt air, as well as fresh and salt water.—Amercoat Corp.

84*R*

Coatings, Protective—This data sheet describes Amercoat #88, designed to protect concrete, plaster, masonry from water penetration, staining, weather etc. —Amercoat Corp.

85*R*

Coatings, Protective—Bulletin 100 describes a wide range of protective coatings. Included in Bulletin are the four classes of corrosive areas broken down as to severity. Also included is description of coatings, physical and chemical properties, and suggested applications. —Carboline Co.

86*R*

Coating, Protective—The use of Carbomastic epoxy-tar coatings have various advantages in conditions such as high humidity, hydrogen sulphide, water immersion, tank linings and heavy duty maintenance are shown in Bulletin 803. Corrosion charts show resistance of Carbomastics in each atmosphere—Carboline Company

87*R*

Comminutor—Bulletin 185-D presents complete data, details and installation information on the company's comminutor.—Chicago Pump Co.

88*R*

Compacting Mill—Literature describes compactor and equipment used to provide a low-cost, mechanical means for converting or upgrading particle size, for controlling product density and product solubility factors.—Allis-Chalmers Mfg. Co.

89*R*

Concrete Pressure Sewer Pipe—A folder discussing features and standards of concrete pressure sewer pipe.—Price Brothers Co.

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90*R*

Concrete Pressure Water Pipe—A booklet explaining and illustrating the proper method of laying concrete pressure pipe. The steps discussed are: digging the trench; checking grade; handling the pipe; lubricating joint rings; making the joint; checking the gasket; grade and line changes; completing the joint; bedding the pipe; and the use of pull jacks.—Price Brothers Co.

91*R*

Concrete Tank Design—Bulletin T-19—An 8-page Technical booklet on the design of prestressed concrete tanks for water supply use.—The Preload Company, Inc.

92*R*

Concrete-Treating—Folder covers use of sodium silicate to make concrete harder, dustproof, acid-resistant and moisture-resistant. Cleaning concrete also detailed.—Philadelphia Quartz Company

93*R*

Construction Tools—Illustrated 4-page bulletin covers rock drills, paving breakers, diggers, spades and tampers with full variety of standard and specialized steels and other accessories.—Schramm, Inc.

94*R*

Control Panels—A new booklet (4543) which describes the many types of control cubicles furnished for integrating and centralizing the control of water-conditioning systems. These cubicles provide semi-automatic or fully automatic control—The Permutit Co.

95*R*

Controllers—Catalog C100-1A describes Tel-O-Set Miniature pneumatic instruments for measurement and control in water filtration plants—Minneapolis-Honeywell Regulator Co.

96*R*

Controllers—Catalogs 900 and 950 include detailed specifications and control action descriptions for both mechanical and pneumatic controllers.—Simplex Valve & Meter Co.

97*R*

Copper Sulphate—Two booklets on the use of copper sulphate. "Copper sulphate in control of Microscopic Organisms", and "Copper sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains."—Phelps Dodge Refining Corp.

98*R*

Copper Sulphate—A 13-page booklet describing the use and application of sulphate in water treatment and algae control, and containing charts of chemicals required for various treatments.—Tennessee Corp.

99*R*

Corrosion Control—This bulletin presents the uses and advantages of Calgon Composition TG in treating cooling water systems and municipal water systems to control the formation of corrosion—Calgon Company Div. of Hagan Chemicals & Controls, Inc.

100*R*

Curb Lock—A folder on the Bremer Curb lock that positively controls water cut offs. The unit will not corrode and can be used over and over.—Bremer Brease, Inc.

101*R*

Cutter, Hydraulic—Form 117 shows the Wheeler hydraulic cutter in action—cutting water main in-the-line.—Wheeler Mfg. Corp.

102*R*

Cutters, Water Main—Form 121 gives instructions for using the new auxiliary ram assembly cutting cast iron or cast iron cement lined pipe 12" through 18" in diameter.—Wheeler Mfg. Corp.

103*R*

Defoamant and Foam Control—Technical data sheet provides information on Foamwilt, an effective all-weather defoamant. Desirable characteristics and test results from various sewage plants are given, along with physical properties.—Fine Organics, Inc.

104*R*

Degritting Clarifier—This bulletin, Number 6412, describes the design, operation and advantages of a new degritting device adaptable to both primary Clarifiers and Dorr Clarigester. Also included are installation photographs and sectional elevation drawings of typical grit handling facilities of this new design.—Dorr-Oliver Inc.

105*R*

Degritting Sewage—Bulletin #2508 describes use of the DorrClone classifier as a grit removal unit. Description, operation, applications and advantages of this new method are included with specifications and illustrations.—Dorr Oliver Inc.

106*R*

Demineralization—This 20-page bulletin outlines the principles of demineralization by ion exchange. Gives details of equipment arrangement, characteristics of ion exchange resins, equipment and resin specifications.—The Permutit Co.

107*R*

Demineralizers—Bulletin WC-111 discusses the design, theory, and equipment of ion exchange systems in detail. A cost estimating curve, system selection chart and other features are also included.—Graver Water Conditioning Co.

108*R*

Densludge Digestion System—A 16-page bulletin describes the development, equipment, operation, typical applications and design loadings of this new sewage sludge digestion system and the means by which digester capacity requirements are substantially reduced.—Dorr-Oliver Inc.

109*R*

Desanding System—Literature describes and illustrates the DorrClone desanding system for water supplies.—Dorr-Oliver, Inc.

110*R*

Detritor—Bulletin #6411 describes design and specifications of two types and special designs of this grit removal unit together with basic requirement considerations, graphs and operating data in 22 pages.—Dorr-Oliver, Inc.

111*R*

Diatomite Filter—Full engineering details on a complete system which guarantees 98% solids removal from sewage and industrial waste plant effluents are available in an 8-page bulletin—Yeomans Bros. Co.

112*R*

Diatomite Filters—Bulletin 1860-PI and 1860.20 on diatomaceous earth filters.—Proportioneers, Inc.

113*R*

Differential Pressure Transmitter—Catalog 10B1465 describes new force-balance Differential Pressure Transmitter featuring measuring circuit parts completely sealed off in silicone oil and adjustable damping directly within the measuring circuit itself.—Fischer & Porter Co.

114*R*

Diffusion Plates & Tubes—This booklet describes fully porous ceramic-bonded plates and tubes for both air and gas diffusion. Also covered is their application to the activated sludge process and to other processes requiring uniform bubble diffusion.—The Carborundum Co.

115*R*

Digester Cover Roofing—A new concept in roofing for digester floating covers is described in bulletin 333. This roofing is said to provide longer life with better insulation and minimum maintenance.—Pacific Flush Tank Co.

116*R*

Digester Sludge Heater—Bulletin tells how this Heater combines concentric tube heat exchanger, separate fire tube boiler and control panel to give absolute automatic control over each function.—Walker Process Equipment, Inc.

117*R*

Digestion Equipment—Bulletin 185-D describes in detail advantages, design, construction and operation information on the company's Catalytic Reduction Process for accelerated sludge digestion.—Chicago Pump Co.

118*R*

Distributor "Water-Wheel" Distributor—For trickling filter systems up to maximum flow of 50,000 g.p.d. Eight-page catalog details operation, design and specifications.—Yeomans Brothers Company.

119*R*

Ditcher—16 page catalog featuring the Gar Wood-Buckeye Model 305, 307 and 308 ditchers. The machines are illustrated in detail as well as in action to show their application in utility work. Complete specifications are also listed. Gar Wood manufactures a complete line

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of wheel and ladder-type ditchers for all ditching operations—Gar Wood Industries

120*R*

Double Suction Pumps—This bulletin describes and illustrates type M horizontally split case double suction pumps. —C. H. Wheeler Mfg. Co.

121*R*

Double Suction Split Case Pump—4 page bulletin No. 1200 describes double suction, horizontally split case centrifugal pumps for long-life, low-cost municipal water pumping service.—The Weinman Pump Mfg. Co.

122*R*

Drafting, Color-Coded—How reading of complicated drawings can be greatly simplified by color-coding is described in bulletin on Mars-Lumochrom pencils. All 24 colors reproduce perfectly; drawings are waterproof, easily erasable, do not smear or fade.—J.S. Staedtler, Inc.

123*R*

Drafting on Mylar—Drafting that is smearproof on matte-surface film is described in literature on revolutionary Mars-Lumograph Duralar pencil. Has plastic, rather than graphite, base. Drawings are completely washable and erasable, won't smudge, reproduce as sharp as India Ink originals.—J. S. Staedtler, Inc.

124*R*

Effluent Sampler—Bulletin describes the sampler and gives operating instructions. —Phipps & Bird, Inc.

125*R*

Ejectors Shone® Pneumatic Sewage Ejectors—Units with mechanical control, warranted for 25 years, are described in a 12-page catalog. Electrode-controlled units covered in separate 8-page catalog. A pneumatic ejector manual details the complete line in 48 pages. —Yeomans Brothers Company.

126*R*

Electrical Control Panels—This bulletin describes typical custom electrical control panels for sewage lift stations, water and sewage plants.—Smith & Loveless, Inc.

127*R*

Electric Motors—This bulletin contains the line of U.S. Motors. Descriptions and full-color illustrations are included of open-type Uniclosed designs, totally-enclosed and explosion-proof types, Varidrives, Syncrogears, and right-angle worm gear models; also vertical motors and Verticlosed hollowshaft types.—U.S. Electrical Motors, Inc.

128*R*

Elevated Steel Tanks—A 24-page booklet discusses Horton Elevated Steel Tanks of Large Capacity and describes the advantages of using large elevated steel tanks to provide gravity pressure. Also contained, detailed information on the design and construction of the tanks and 12 photographs of actual installations, a table of sizes, and page of drawings showing construction details.—Chicago Bridge & Iron Co.

129*R*

Elevated Steel Tanks—A 20-page brochure describing Horton ellipsoidal bottom elevated steel tanks of welded construction. Illustrates a number of industrial and municipal tanks, describes dual service of tanks for general use and fire-protection. Lists table of standard capacities up to 500,000 gallons.—Chicago Bridge & Iron Co.

130*R*

Elevated Steel Tanks—This 20-page booklet includes dimensional data and capacities for 6 basic tank types, in addition to many installation photographs and descriptions. A cut-away view shows such accessory equipment for these tanks such as swivel ladder, stub overflow, steel balcony and vent.—Pittsburgh-Des Moines Steel Co.

131*R*

Elevated Water Tanks—A 16-page brochure describing the Watersphere and Waterspheroid. The modern structures are used in municipal and private water systems to provide gravity pressure for general service and fire protection, and this use is described in the booklet. A portion of the booklet illustrates the "skyline advertising" use of these structures.—Chicago Bridge & Iron Co.

132*R*

Elevated Water Tanks-Aluminum—A small number of reprints remain of an article on the twin aluminum elevated water tanks, which Graver built for the new plant of Kaiser Aluminum & Chemical Corp. at Ravenswood, W. Va. This reprint is taken from Welding Engineer and deals chiefly with the welding and erection aspects of these two tanks. They are certainly among the first aluminum elevated tanks in the world.—Graver Tank & Mfg. Co., Div.—Union Tank Car Company

133*R*

Elevated Water Tanks—Reprints of Graver's award-winning series of full-color inserts are available upon request. These handsome ad reprints serve two purposes: they provide attractive office decorations when framed and they furnish interesting case histories of solutions of specific water storage problems. The reversal side of certain of the reprints tabularize usefully the standard sizes of elevated tanks and pump suction tanks.—Graver Tank & Mfg. Co., Div.—Union Tank Car Company

134*R*

Engine Diesel—Literature describing a turbo-supercharged opposed-piston diesel engine, said to be the smallest and lightest commercial diesel in its hp range.—Fairbanks, Morse & Co.

135*R*

Engines—A series of 4 bulletins describing Climax 4, 6, 8 and 12 cylinder gas engines in a range of sizes up to 600 hp. These engines are capable of operation on natural gas, butane, sewage gas, gasoline or a combination of any two of these fuels.—Climax Engine Manufacturing Co.

136*R*

Engines—A series of 4 bulletins describing Roiline 6, 8 and 12 cylinders gas engines in a range of sizes up to 685 hp. These engines are capable of operation on natural gas, butane, sewage gas, gasoline or a combination of any two of these fuels.—Waukesha Motor Co.

137*R*

Engines, Sewage Plant—A 20-page bulletin showing dual fuel engines, diesel engines and spark ignition engines. Contains engine selection chart, comparison fuel gas analysis chart and others.—Worthington Corp.

138*R*

Epoxy Linings for Sewer Pipe—Catalog describing a 100% solids epoxy resin lining extended with an inert filler which gives acid resistance to concrete sewer pipe—material can be applied for new pipe or in existing lines, 24"-144" in diameter, thickness of ⅛" to ½"—Centriline Corp.

139*R*

Water Treatment Equipment—Flash mixers and contactors, clarifiers, reactor-clarifiers, flocculation mechanisms, feeders and other equipment are described in new Bulletin SM-1013.—The Eimco Corp.

140*R*

Fabrication & Erection: Steels & Alloys —The Echo, employee magazine of Graver Tank & Mfg. Co., provides interesting case histories of the uses of Graver-built tanks and vessels for many different purposes and products. Each issue offers examples of steel and alloy plate work at significant installations in petroleum, chemical, atomic energy and similar industries. Very fully illustrated, it suggests the many applications of plate construction.—Graver Tank & Mfg. Co., Div.—Union Tank Car Company

141*R*

Ferric-Floc—A 38-page booklet describing the use and application of ferric sulphate in all phases of coagulation.—Tennessee Corp.

142*R*

Filter, Automatic Backwash—Bulletin-46-A illustrates and describes how this automatic backwash sand filter traveling carriage cleans the compartmented filter bed section by section without interrupting the normal filtering operation.—Hardinge Company, Incorporated.

143*R*

Filter, Automatic Valveless—This bulletin describes the completely automatic gravity sand filter that uses no valves, pumps or flow controllers.—The Permutit Co.

144*R*

Filter Bottoms—Information on FECO "FRE-FLO" Filter Bottoms is given in bulletin 1-32. Complete information and typical drawings upon request.—Filtration Equip. Corp.

145*R*

Filter Media—Bulletin on "Anthrafilt" tells the reasons why selected, graded, crushed anthracite is superior to sand as a filtering material.—Anthracite Equipment Corp.

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146*R*

Filter Operating Console—Product Specification G71-8 describes styles of steel control consoles for operation of rapid sand filters. Available in four standard colors, each console has inclined surface for optimum readability of instruments and efficient operation of hand adjustments.—Bailey Meter Company.

147*R*

Filter Plants—Detailed, removal of iron, manganese, taste, odor and gas. This new bulletin is highly illustrated. Has the problems listed and the answers given.—General Filter Co.

148*R*

Filter Table, Automatic—Bulletin 2200 is a 4-page catalog which furnishes detailed information on the use and operation of the Simplex Electro Pneumatic Filter Control Table.—Simplex Valve & Meter Co.

149*R*

Filter Underdrains—Brochure gives complete information on "Criscrete" filter underdrains.—M C G Company.

150*R*

Filter Underdrains—Shape bulletins TF-5 and TF-8 contain useful information on Natco salt glazed Tri-Filter Blocks, which are available for both standard and high rate trickling filter systems—Natco Corp.

151*R*

Filters—General information on Roberts filters for municipal water purification, industrial water rectification, swimming pool recirculating systems and pressure filters.—Roberts Filter Mfg. Co.

152*R*

Filters, Pressure—Bulletin 2225 describes the operation and design features of pressure filters, both vertical and horizontal. Contains details of auxilary equipment including Permutit Multiport Valve, also installation photos and specifications.—The Permutit Co.

153*R*

Filters, Vacuum—Bulletin 1860.20-1 describes Model VFC corrosion resistant, fiberglass construction, which makes this filter impervious to algae, oils, most chemicals, bacteria, dirt, etc. Low initial, operating and maintenance costs.—B-I-F Industries, Inc.

154*R*

Financing Water and Sewage Works—This booklet is designed planning and financing water and sewage works. It points out the need for sanitation facilities and stresses the revenue bond method of financing. Also discussed are factors to be considered in a determination of fair rate schedules for water and sewage charges.—Portland Cement Association

155*R*

Fire Hydrants—44 page bulletin no. 5710 gives complete information on the Darling B-50-B Fire Hydrants with Ball Bearings for ease of operation and "O" Rings instead of the usual stuffing box.—Darling Valve & Mfg. Co.

156*R*

Fire Hydrants—This bulletin describes the Corey-type fire hydrants and Iowa waterworks valves.—Iowa Valve Co.

157*R*

Fire Hydrants—This 18-page catalog illustrates and describes the Ludlow slide gate type of hydrant.—Ludlow Valve Manufacturing Co., Inc.

158*R*

Fire Hydrants—A 20-page catalog H53 showing a complete line of AWWA approved hydrants together with detailed illustrations of construction, mechanical drawings, bills of materials, approved construction, installation and inspection data.—A. P. Manufacturing Co.

159*R*

Fire Hydrants—Literature on Mathews modernized, Mathews flanged barrel and R. D. Wood swivel joint fire hydrants conforming to latest AWWA specifications and of designs to meet any requirement. Also lists gate valves.—R. D. Wood Co.

160*R*

Fire Hydrants & Gate Valves—Compact brochure describes all the features of Mueller AWWA Improved Fire Hydrants and AWWA Gate Valves. Many other illustrations show the types of hydrants available, and the more popular end combinations to be had in gate valves, whether with "O" ring seals or conventional packing—Mueller Co.

161*R*

Fire Hydrants, Gate Valves, Tapping Machines, etc.—A 12-page condensed catalog M58, available in either Spanish or English edition, showing Smith line of products. Hydrants, gate valves, tapping machines, sleeves, tapping valves, cut-in sleeve & valve, inserting machines & valves, check valves and repair sleeves.—A. P. Smith Manufacturing Co.

162*R*

Fire Pumps—Literature tells of fire and low-pressure (booster) pumps approved by Underwriters Laboratories, Inc., or Associated Factory Mutual Fire Insurance Companies for heads from 50 to 145 psi and capacities from 500 to 2500 gals. per minute.—Allis-Chalmers Mfg. Co.

163*R*

Flange Gaskets—A series of seals for ASA-API flanges which are re-usable, eliminate cleaning or re-surfacing of flange faces, do not wear due to pulse or vibration. Seal to 15,000 PSI or high vacuum. Catalog #5804.—Parker Seal Co., Div. of Parker-Hannifin Corp.

164*R*

Floating Covers—This brochure gives design and application data on positive, non-tipping construction of Chicago-Wiggins Pontoon Digester Floating Covers.—Chicago Pump Co.

165*R*

Floating Covers—A bulletin that covers in 40 pages the theory of control digestion with digester design considerations, digester operation and floating cover construction details.—Pacific Flush Tank Co.

166*R*

Float-Treat System—For water, sewange and wastes treatment. Bulletin describes in detail the process in which suspended organic matter and usual chemical flocs are removed from process liquids by flotation.—Chain Belt Co.

167*R*

Flocculation—Bulletins 2W66 and 2W72 cover impeller type and reel type flocculation units and rapid mixers for water and waste treatment.—Walker Process Equipment, Inc.

168*R*

Flocculation Equipment—This bulletin covers the pretreatment of water. Rex Floctrol design and arrangement are covered in detail. Information on Rex Slo-Mixers and Rex Flash-Mixers is included.—Chain Belt Co.

169*R*

Flocculation Equipment—An 8-page booklet, "Equipment For Chemical Flocculation" illustrates and discusses Link-Belts line of conveyors and elevators for handling chemicals and flash and straightline mixers.—Link-Belt Co.

170*R*

Flocculators—Bulletin 6971 contains a description of Dorr-Oliver equipment used to perform the two basic steps of flash mixing and flocculation.—Dorr-Oliver Inc.

171*R*

Floor Grating—A bulletin discussing riveted, pressure locked, types of aluminum floor grating. General instruction for ordering and charts on safe loads are given. Borden safety steps are also discussed.—Borden Metal Products Co.

172*R*

Floor Grating—Catalogs available on steel, stainless and aluminum grating. Contains safe load tables, how to order information, specifications. Stair tread data and Drain Grating.—Kerrigan Iron Works, Inc.

173*R*

Flotation—This bulletin discusses the Graver Flotation Unit and shows the design features. The various uses and advantages of flotation are discussed.—Graver Water Conditioning Co.

174*R*

Flow Measurement—Bulletin 115-LIA and 115-LIB on Dall Flow Tube; Bulletins 110-NI & 110-NIA on Venturi Tubes; 135-F2A & 135.20-I Kennison Nozzles; and 380-K4A & 380-K4B on Propeloflo meters.—Builders-Providence, Inc.

175*R*

Flow Measurement—Bulletin 1200 ML Meter, Bulletin 1201 MN Meter, Bulletins 400, 401 & 402 Venturi Tubes, Bulletin 601 Electronic Differential Meter—Burgess-Manning Company.

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176*R*

Flow Measurement—Bulletins 402, 500, 700, 750, and 950 cover equipment manufactured by the company for fluid flow measurement.—Simplex Valve & Meter Co.

177*R*

Flowmeter, Magnetic—Catalog 10D1416 discusses principle and operation of magnetic flowmeters. Gives advantages and specifications of F & P unit.—Fischer & Porter Co.

178*R*

Flow Tubes—Bulletin 115.20-1 provides complete information about the new low cost corrosion-resistant plastic insert Dall Flow Tube to meter acids, alkalies, slurries and gases.—B-I-F Industries, Inc.

179*R*

Flow Tubes—The Gentile Flow Tube, used for metering water, air, slurry, raw sewage sludge, paper stock, etc. Advantages of the flow tube are given, along with a performance table, head loss and differential charts. Photographs of actual installations and cut-away drawings are included.—Foster Engineering Div., General Controls Co.

180*R*

Fluo-Chlorinator—Catalog 70F140 describes Fischer & Porter Fluo-Chlorinator designed for the simultaneous addition of both chlorine and dissolved fluorides, Either substance can be added separately—Fischer & Porter Co.

181*R*

Fluoride Feeders—This bulletin 50-K3A describes the Omega fluoridizer for accurate continuous volumetric feeding of fluoride compounds.—Omega Machine Co.

182*R*

Garbage and Refuse Disposal—Bulletin describes newer procedures and discusses use of Cifon and Foamwilt in this application.—Fine Organics

183*R*

Gasket Type Joint, Cast Iron Pipe—A brochure on Fastite joint pipe for water, sewage and other liquid service. The brochure gives a complete description of pipe joint, photograph and text show the proper methods of assembly in the field, specifications and photograph of typical installations. Tables containing weights, working pressures and recommended deflections are also included—American Cast Iron Pipe

184*R*

Gaslifter, Digester Circulator—Bulletin describes the gaslifter as the simplest and most efficient digester mixer available—Walker Process Equipment, Inc.

185*R*

Gas Meters—Bulletin M-258 covers rotary positive displacement meters for measuring all types of gases, at flow rates ranging from 4000 CFH to 1,000,000 CFH, designed for service at 26, 60, and 125 PSIG.—Roots-Connersville Blower

186*R*

Gas Pumps—Bulletins S59-G and S65-C covering gas pumps of the rotary positive pressure class, featuring oil free, metered delivery of gas up to 10 psig, single stage.—Sutorbilt Corp.

187*R*

Gas Safety Equipment—This bulletin provides capacity curves along with detailed drawings of a complete line of gas safety equipment designed expressly for sewage sludge gas. The bulletin also pictures a number of typical installations and provides a standard layout of a digester gas piping system.—Pacific Flush Tank Co.

188*R*

Gate Valve, AWWA—This bulletin illustrates and describes list 13A AWWA Rensselaer gate valve as well as high and low pressure valves.—Ludlow Valve Mfg. Co. Inc.

189*R*

Gate Valve, Bonnetless—Literature describes fabricated bonnetless gate valve, designed for handling fibrous, viscous and slurry type flows.—DeZurik Corp.

190*R*

Gate Valves—This 36-page bulletin illustrates and describes AWWA gate valves, high and low pressure valves, as well as miscellaneous waterworks appurtenances.—Ludlow Valve Manufacturing Co., Inc.

191*R*

Gate Valves—A 64-page catalog V56 showing a complete line of AWWA approved valves with all types of controls, mechanical drawings, bills of materials, optional construction, and technical data.—A. P. Smith Manufacturing Co.

192*R*

Glazed and Unglazed Face Brick—Light Construction Catalog SB-59 describes and illustrates the wide range of Natco Standard, Roman, Norman and SCR Face Brick—Natco Corp.

193*R*

Gratings—Booklet discusses in detail the construction, design and load capacity of corrosion resistant aluminum gratings. Also contains information on aluminum stair and ladder treads.—Washington Aluminum Co.

194*R*

Gravity Sewer Pipe—New crushing strengths, 4 page folder AP-19 describes five engineering classifications of K&M asbestos-cement gravity sewer pipe. Intended as an aid to engineers to help them meet more exactly, the requirements of soil conditions, as well as depth of trench, width of trench; manner of bedding. Crushing strengths, sizes and a crushing table based on the Marston formula are presented.—Keasbey & Mattison Co.

195*R*

Grinders—Complete data on grinders for sewage screenings is given in this catalog. It also covers sludge collectors and screens.—Jeffrey Mfg. Co.

196*R*

Grit Collectors—The 5 basic types of Rex grit collectors, making a broad comprehensive line, are covered in this bulletin.—Chain Belt Co.

197*R*

Grit Removal—This bulletin and technical supplement describe the grit conveyor, grit hydrowash, grit elevator and "American" Camp regulator for grit removal by velocity regulation and mechanical means.—American Well Works.

198*R*

Grit Removal—Catalog covers grit collectors, scraper, elevator-spiral and V-bucket type. Dimension drawings, illustrations and detailed description.—Jeffrey Mfg. Co.

199*R*

Grit Separators—Eimco-Process separators are built in five separate types, to handle any specialized application need. Variable speed drives for varying flows. Bulletin SM-1007—The Eimco Corp.

200*R*

Gunite—This 48-page booklet illustrates Gunite for repair and restoration to all existing concrete and masonry structures. Typical specifications are listed.—Pressure Concrete Co.

201*R*

Heat Exchanger—This brochure illustrates and describes the Cyclotherm Digester heater and heat exchanger.—Chicago Pump Co.

202*R*

Heat Exchanger—Bulletin 6281 on the spiral heat exchanger, an external element of the spiral flow type for controlling digestion tank temperatures—Dorr-Oliver Inc.

203*R*

Heat Exchangers—A 28-page bulletin presents a concise explanation of effective digester heating, scum control and operation of the P. F. T. Sludge Heater. Bulletin includes a method of computing size of heater and heat exchangers and table with complete size and operating data.—Pacific Flush Tank Co.

204*R*

Heat Transfer—This brochure gives detailed information on Chicago-Selas heat transfer system for superior sludge heating service.—Chicago Pump Co.

205*R*

High Capacity Chlorinator—20 page catalog 70-15 describes features, construction and application of vacuum-type, solution-feed, high capacity gas chlorinator suitable for manual, semi-automatic or fully automatic operation in capacities from 60 to 8,000 pounds of chlorine per 24 hours.—Fischer & Porter Co.

206*R*

Horizontal Compressors—This 24-page bulletin discusses single stage, 10-150 psi, 5-2000 cfm compressors. It also

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contains drawings and specifications.—Worthington Corp.

207*R*

Hydrant's Fire—Twelve page circular describing standard, traffic and flush models of fire hydrants, how to install, lengthen and repair, and special features. Circular No. 22—M & H. Valve and Fittings Co.

208*R*

Hydra-Pneumatic Controls—Literature describes the new Flow-Trol Hydra-Pneumatic system for combination air-water valve control—F. B. Leopold Co., Inc.

209*R*

Hydro-Classifiers—Bulletin 39-C describes the Hydro classifier design that is similiar to that of the circular clarifier and thickeners with a generally shallower tank and adjustable weir.—Hardinge Co., Inc.

210*R*

Hydrofluosilicic Acid—A brochure on Hydrofluosilicic acid and it's uses for fluoridation by municipalities.—International Minerals & Chemical Corp.

211*R*

Hypochlorination—This booklet discusses various chlorination practices with HTH in granular and tablet form. Eight tables pertaining to chlorination are included.—Chemicals Div., Olin Mathieson Chemical Corp.

212*R*

Hypochlorinator—A bulletin describing a Heavy Duty Midget Chlor-O-Feeder as an all purpose, positive displacement, diaphragm pump for fluids such as hypochlorite, pH correctives, and abrasive slurries. The midget delivers 0.5 to 9 gph against pressures up to 85 pisg. Bulletin 1201-2.—Proportioneers Inc.

213*R*

Incinerators—Bulletin 111C gives complete information on mechanically stoked incinerators for municipal use.—Morse-Boulger Destructor Co.

214*R*

Incinerators—This new bulletin discusses the disposal of sludge, screening, grit and skimmings in a Nichols Herreshoff multiple hearth furnace. Information includes technical data on burning, drying, fly ash removal, ash handling plus an illustrated description of the equipment and its operation.—Nichols Engineering & Research Corp.

215*R*

Industrial Waste Treatment—66 page catalog outlines entire line of equipment for industrial waste treatment.—Jeffrey Mfg. Co.

216*R*

Industrial Waste Treatment—Bulletin 4486 discusses the general types of industrial wastes and the problems involved in selection of waste treatment systems. Also, details used for the treatment of industrial and municipal wastes—Permutit Co.

217*R*

Information System—Bulletin E72-1 explains how dozens of field measurements, made locally and/or remotely, are received and displayed in digital form by the Metrotype Information System. Equipment described may be furnished as part of complete measuring and controlling system or may be used with existing primary measuring devices.—Bailey Meter Company

218*R*

Inserts Venturi Tubes & Nozzles—Bulletin 100 is a 4-page catalog showing types and installation drawings of the Simplex Type TG Tubes and Nozzles.—Simplex Valve & Meter Co.

219*R*

Instrument, Accessories—60-page catalog containing specifications, part numbers and prices on the more than 250 commonly furnished Foxboro instrument parts and supplies.—Foxboro, Co.

220*R*

Instrumentation—Data sheets for instrumentation on water and sewage treatment plants; the different types of equipment used and their application.—Fischer & Porter Co.

221*R*

Instrumentation—A 16-page booklet covering Foxboro instruments manufactured for water and sewage works applications.—Foxboro Co.

222*R*

Instrumentation—Bulletin B96-1 includes detailed description of control systems for all phases of municipal and industrial water treatment processes—Minneapolis-Honeywell Regulator Co.

223*R*

Instruments and Controls—General Bulletin G15-1 describes over one hundred measuring, transmitting, receiving, recording, and indicating instruments and control components. Complete index to product literature is included, plus addresses and phone numbers of all twenty-four district offices.—Bailey Meter Company

224*R*

Instruments, Filter Plant—Bulletins 1002, and 1100 illustrate and describe filter plant gauges and summator equipment.—Simplex Valve & Meter Co.

225*R*

Instruments, Flow Measurement—General catalog 005 presents equipment on meters and gauges for flow measurement.—Simplex Valve & Meter Co.

226*R*

Joint Cut-In Valves—Specifications, installation illustrations and explanatory text are included in this bulletin on mechanical joint cut-in valves and sleeves.—A. P. Smith Mfg. Co.

227*R*

Jointing Compound—A complete data book on Hydro-Tite, the self-caulking jointing compound for cast iron water mains.—Hydraulic Development Corp.

228*R*

Joints, Rubber—20 page booklet describing Tylox rubber gaskets for leak-proof coupling of concrete and vitrified clay sewer pipe—Hamilton Kent Mfg. Co.

229*R*

Joints, Slip—Brochure on Crispin slip joints describing safe, fast way to remove and replace fixtures when repairing lines etc.,—Multiplex Mfg. Co.

230*R*

Lift Stations—Bulletin No. 121 describes in detail the company's UT Packaged Underground Lift Station with Flush-Kleen Sewage pumps—Chicago Pump Co.

231*R*

Lift Stations Prefabricated Lift Stations—Factory-built underground sewage lift stations equipped with centrifugal pumps or pneumatic ejectors are detailed in separate 8-page catalogs.—Yeomans Brothers Company.

232*R*

Lime Slaker—Either high calcium or poor grades of lime are slaked in the form of a paste which is then diluted and fed as lime slurry. High paste temperature results in complete slaking without the need for hot water. Arranged for continuous grit removal. Bulletin 255-A—Infilco Incorporated

233*R*

Lime Slakers—Bulletin 40-E1B & 40.20-1 covers equipment for lime slaking at 175 to 10,000 lb. per hour with thermostatic water control and vapor removal devices.—Omega Machine Co.

234*R*

Lime Slakers—Bulletin TP-14-M-1 describes a new lime slaker which proportions water and quick-lime automatically and continuously to slake lime as a paste. External hot water and heat exchanger equipment are eliminated. There are two sizes: 1000 and 4000 lbs. per hour.—Wallace & Tiernan, Inc.

235*R*

Liquid Feeders, Rotodip—Bulletin 65-H12B & 65.20-1 on a volumetric feeder for liquids, including acids, alkalies, or slurries at rates from 0 to 1800 gallons per hour with repeatable accuracy within ±1%.—Omega Machine Co.

236*R*

Loading Assemblies—24-page catalog describes complete line of loading and unloading assemblies with detailed engineering drawings and specifications. Safe, fast, efficient and easy loading of sludge and other fluid materials—OPW-Jordan.

237*R*

Low Pressure Meter—Literature describes a propellor type low pressure line meter for measuring large water volumes in closed conduits.—Sparling Meter Co.

238*R*

Magnetic Propeller Drive Meter—Literature describes this main-line meter,

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incorporating a powerful radial magnet. —Sparling Meter Co.

239*R*

Main Cleaning—Water pressure restored to original capacity without new mains or pumping equipment. Clogged sewers and water pipes cleaned with custom-built power equipment that removes tuberculation and mineral deposits.—Ace Pipe Cleaning, Inc.

240*R*

Manhole Frames and Covers—Descriptive literature and catalog illustrating standard size manhole frames and covers, cast iron inlets and other municipal castings.—Opelika Foundry Co., Inc.

241*R*

Manlift Elevators—For fast inter-floor transportation manlifts as described in 8-page bulletin provide safe travel for personnel or bags and other packaged materials.—Allis-Chalmers Mfg. Co.

242*R*

Mechanical Joint—A catalog describing different types of pipe and fittings connected with mechanical joints—Alabama Pipe

243*R*

Mechanical Joint—This bulletin illustrates and describes the Clow mechanical joint cast iron pipe.—James B. Clow & Sons, Inc.

244*R*

Mechanical Joint—Booklet includes dimensions and weights of mechanical joint cast iron pipe and fittings.—U.S. Pipe & Foundry Co.

245*R*

Mechanical Joint Repair Sleeves—This bulletin describes mechanical joint repair sleeves for repairing cast iron and cement asbestos water main breaks.—Eddy Valve Co.

246*R*

Mechanical Jointed Clay Pipe—A 4-page folder describes the new AMVIT jointed vitrified clay pipe, sizes 4 through 24 inches as a true "built-in" mechanical joint ready for immediate, quick and easy installation. The joint is furnished on all standard fittings, as well as pipe, permitting a bottle tight line.—American Vitrified Products Co.

247*R*

Meter Boxes—Brochure and catalog illustrating cast iron meter boxes, manhole frames and covers, cast iron inlets and other municipal castings.—Opelika Foundry Co., Inc.

248*R*

Meter Repair—This complete, well illustrated 16-page manual for the water meter shop tells how to set up a repair and test program, how to lay out the shop, and step-by-step repair instructions. Indicate frost-proof or split case meters—Neptune Meter Co.

249*R*

Meter Setting and Testing—Catalog 56 contains complete listing of water meter setting and testing equipment along with information on good meter setting practice under various conditions.—Ford Meter Box Co. Inc.

250*R*

Meter Testing, Water—A 40-page book on methods and equipment for testing meters, including information on meter shop layout, meter performance, and a bibliography on meter maintenance.—Ford Meter Box Co., Inc.

251*R*

Meters, Magnetic Water—Bulletin W-811 presents the most important advance in water meter history, the all-new magnetic Rockwell Sealed Register Water Meter. This 24-page bulletin illustrates and describes the principle and design on this new meter. The Sealed Register is available in sizes, ⅝" and ¾" x ¼"—Rockwell Manufacturing Company

252*R*

Meters, Sewage Gas—Bulletin C-5200 describes the company's entire line of sewage gas meters, both large and small capacities.—Rockwell Manufacturing Co.

253*R*

Meters, Water—General catalog illustrates and describes Badger, Disc meters, frost proof and split case types, ⅝" through 4" sizes. Compound meters 2" through 10" sizes. Turbine meters 2" through 12" sizes. Multiple meter testers and meter coupling yokes.—Badger Meter Mfg. Co.

254*R*

Meters, Water—Catalog gives full details of American disc type water meters, both frost bottom and solid casing types, sizes ⅝ to 6 inches.—Buffalo Meter Co.

255*R*

Meters, Water—This catalog gives details and specifications of Trident meters from ⅝ to 16" in size. Frostproof and split-case meters for household use, style 3 meters for intermediate flows, and larger compound, crest and Protectus fire service meters are also covered.—Neptune Meter Co.

256*R*

Meters, Water—Direct reading propeller type units for metering water and other free-flowing, non-corrosive liquids are described in this bulletin 65.20-1—Omega Machine Co.

257*R*

Microstraining—A series of folders on test results and operating data illustrating the Microstraining process. Economic removal of microscopic debris and plankton render this method of automatic filtration invaluable in water treatment, pollution prevention, conservation & water re-use problems.—Glenfield and Kennedy, Inc.

258*R*

Mixflo Pumps—A 16-page bulletin on mixflo pumps for irrigation, drainage, sewage disposal, condenser circulating and low water supply. Performance curves and drawings are also included. —Worthington Corp.

259*R*

Mixing—Bulletin #5782 illustrates and describes the "FM" liquid mixers with tables and application recommendations. —General Filter Co.

260*R*

Mobile Pipe Cleaning—New bulletin describes modern mobile pipe cleaning equipment ready on a moments notice to solve any water main cleaning project. Trained crews operating specially designed power-driven tools clean mains with maximum efficiency and speed. Recognized experts in the field, old pipes are made new again at a fraction of the cost of new pipe installation. —Ace Pipe Cleaning, Inc.

261*R*

Modern Sewage Treatment—This 12-page bulletin describes the distinguishing characteristics, types, sizes, applications and operation of major Dorr-Oliver sewage treatment equipment and presents a number of typical plant flowsheets. Also included are photographs and line and wash drawings of various units.—Dorr-Oliver Inc.

262*R*

Modern Water Tanks—A new 4-page folder describes the newest design for elevated tanks for water storage—the Graver "Aquatore". This new form utilizes a torus tank on a flared columnar support. Besides its new and distinctive appearance, Graver engineers have been able to secure in this attractive design the advantage of certain economies in cost, as a result of savings in fabricating procedures. By its toroidal design, it provides for more uniform pressures throughout the distribution system.—Graver Tank & Mfg. Co., Div.—Union Tank Car Company

263*R*

Monorake—This 12-page bulletin presents the Dorrco Monorake. It describes the design, types and sizes, operation and advantages of this mechanism for cleaning rectangular sedimentation basins and tabulates actual maintenance costs from a number of installations.—Dorr-Oliver Inc.

264*R*

Motor, Explosion-Proof—Literature describes a new line of totally enclosed, explosion proof motors.—Fairbanks, Morse & Co.

265*R*

Municipal Sanitation—Bulletin No. 6043 "Seven Developments for Municipal and Industrial Sanitation" assembles for review in a single brochure data on seven major D-O equipment designs and process developments introduced in the past three years. It includes photographs, line and wash drawings and descriptive sketches of each development. —Dorr Oliver Inc.

266*R*

Municipal Water Conditioning—This general bulletin WE-113A discusses the various types of equipment available from the company to handle municipal water problems.—Graver Water Conditioning Co.

267*R*

Odor Control—Illustrated Technical Bulletins available describing Cloroben.

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A sanitation chemical which controls odors in sewage treatment plants, pump and lift stations, wet wells, force mains, drying beds, filters, sanitary landfills, storm drains, catch basins, garbage trucks, etc.—Cloroben Chemical Corporation

268R

Odor Control—Technical Data Sheet provides information on Cifon, which controls odor in sanitation disposal, sewage disposal plants in the raw, sludge storage tank; for grit disposal, sand filter beds; effluent—Fine Organics, Inc.

269R

Oxidators—Eimco-Process Oxidators combine sedimentation and aeration in one tank, the air mixing and recirculating previously settled sludge and floc with the influent. Bulletin SM-1005—The Eimco Corp.

270R

Package Treatment Plant—Folder describes the Comple Treator a self-contained complete waste treatment facilities for small plants.—Dorr Oliver, Inc.

271R

Parabolic Flume—Bulletin 801 is an 8-page catalog on the Simplex "S" Flume showing typical installations and descriptive matter concerning dimensions and capacities of this type of parabolic flume.—Simplex Valve & Meter Co.,

272R

PeriFilter System—Combines conventional water pre-treatment and rapid sand filters in a single unit for economies in handling 0.2 to 20 MGD. Bulletin #9042 offers choice of pre-treatment mechanisms with annular filter bed for all conditions.—Dorr-Oliver Inc.

273R

pH Control—This bulletin discusses the use of PH-Plus (½-lb. cakes of fused sodium carbonate) in pH control of swimming pool water and in general industrial water treatment. Covered in detail are various types of feeding equipment in which these slow-dissolving cakes of fused alkali will provide positive and economical alkalinity control.—Chemicals Div., Olin Mathieson Chemical Corp.

274R

Pipe Sewer, Asbestos-Cement—An 8-page, 2-color folder featuring Transite asbestos-cement sewer pipe, lists its advantages, and how it, with the Ring-Tite coupling makes possible tight sewer systems at low installation cost.—Johns-Manville Corp.

275R

Pipe, Water, Asbestos-Cement—An 8-page, 2-color folder featuring Transite asbestos-cement Pressure Pipe, its manufacture, properties and advantages. The folder also shows how, in combination with the Ring-Tite coupling, to install water lines faster to last longer. Various installation photos are included. —Johns-Manville Corp.

276R

Pipe, Ball Joint—A catalog containing instructions, for assembly, weight and dimension tables and different methods of installing the ball joint pipe for river crossings and submarine service —American Cast Iron Pipe Co.

277R

Pipe, Cast Iron Pressure—Facilities brochure describing cast iron pressure pipe in 20′ lengths for water and gas. Brochure describes area serviced, selection of pipe joints available, layout of the plant and method of manufacture.—Griffin Pipe Div.

278R

Pipe Clay—Presents the complete story on clay pipe—National Clay Pipe Mfgr. Inc.

279R

Pipe Cutters—Catalog No. 41 gives descriptive information on Ellis Pipe Cutters for cutting Cast Iron or Steel Pipe in sizes from 4 to 16 inches.—Ellis & Ford Mfg. Co.

280R

Pipe Cutting—Form 102 pictures and describes the Wheeler squeeze and pop cutters which cuts in minutes—water main, soil pipe, asbestos cement pipe, Duriron.—Wheeler Mfg. Corp.

281R

Pipe, Plastic—Complete data and descriptive literature on all types of plastic pipe (ABS, Polyethylene, PVC, Chem-Weld drain pipe, Telec-Con plastic conduit). Recommended applications include water systems, lawn sprinkling systems, swimming pool drain and supply lines, waste and sewerage drain lines.—Southwestern Plastic Pipe Co.

282R

Pipe, Reinforced Epoxy—Illustrated Brochure on Bondstrand, manufactured of interwoven fiber glass filaments impregnated with epoxy resins, heat cured. Corrosion resistant to meet pipe, ducting and tubing needs. Nontoxic, nonflammable and collapse resistant—Amercoat Corp.

283R

Pipe, Sewer, Asbestos-Cement—"Transite® Sewer Pipe," made of asbestos-cement, available in 11 different diameters ranging from 6" to 36" and in 5 new crushing strengths to permit greater efficiency in system design. Ring-Tite(R) Coupling, designed for high-speed assembly, provides tight, long-lasting seal. Easy-to-assemble Transite sewer fittings with Ring-Tite assembly also furnished. For complete information, write for brochure TR-165A (Transite Sewer Pipe), TR-94A (Sewer Design Flow Chart), and DS-366 (Transite Specifications).—Johns-Manville

284R

Pipe Tapping Machines—Folder illustrates and describes the all-new, hand or power-operated Mueller B-100 Drilling, Tapping and Inserting Machine, which is based on proven "double pressure chamber" principle. All major features are shown in large two-color cutaways. Also illustrated are revolutionary new Air and Electric Power Operators developed to give atuomatic feed for faster taps and longer tool life.—Mueller Co.

285R

Pipe, Water, Asbestos-Cement—The installation, operation and maintenance economies of Transite® Pipe and the Ring-Tite® Coupling for pressure water lines are described and illustrated in four pieces of literature available to the water utilities management. They include (1) DS-335—a material specification (2) TR-15A—a Friction Loss of Head and Flow Powergraph (3) TR-160A, in service characteristics and case histories of Transite Water Pipe. Tables of weights, sizes and pressure classes also included.—Johns-Manville.

286R

Pitot Equipment—Bulletin 1301 is an 18-page catalog which describes and furnishes instructions for Simplex Equipment. This bulletin also covers the theory, formulae, notations, tables and curves for use of the pitot recorders.—Simplex Valve & Meter Company

287R

Plastic Pipe—A new bulletin describes the new Ace Riviclor Chemical-Resistant Plastic Pipe, Fittings and Valves. The bulletin includes technical properties, a table of resistance to chemicals, data on sizes, pressures, dimensions, prices for pipe, fittings and valves from ½ to 2 in. Instructions for threading, forming and other installation operations are also given.—American Hard Rubber Co.

288R

Pneumatic Controller—12 page Catalog 53P-4000 discusses motion-balance pneumatic controllers with exclusive regenerative feedback circuit.—Fischer & Porter Co.

289R

Pneumatic Ejector Expelsor® Pneumatic Ejector—Stored air and tankless systems, and a "package" unit with ready-mounted compressor, are detailed in an 8-page catalog.—Yeomans Brothers Company.

290R

Pneumatic Transmitter—Bulletin 285-L2B & 285.20A-1 describes the BalanCel transmitter as a simple force-balance device for transmission of flow, level, and pressure data. Also for the summation, averaging, etc., of two quantities.—Builders-Providence, Inc.

291R

Pool Sanitation—42-page booklet discusses in detail the safe treating of swimming pool water with HTH. Describes the various methods and advantages of disinfecting water with calcium hypochlorite as opposed to other means of chlorination.—Chemicals Div., Olin Mathieson Chemical Corp.

292R

Porous Media—Bulletin describes use of porous ceramic plates and tubes in a wide variety of equipment used in the treatment of water, sewage and industrial wastes. Charts and tables help provide data required in operating units equipped with these porous media.—The Carborundum Co.

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293*R*

Power Sewer Cleaners—current catalog illustrates and describes the improved models of Sewerkings—all-power, automatic, cable type machines which reduce sewer cleaning costs 50%-75% by one-man operation and manhole to manhole reach.—O'Brien Manufacturing Corp.

294*R*

Prefabricated Sewage Plants—Factory built plants shipped as complete plants ready to place in the excavation are described in Bulletin 101. Aerobic Digestion plants use Cavitator® aerator.—Yeomans Brothers Company.

295*R*

Pressure Filters—This bulletin describes the company's line of horizontal and vertical sand and gravel pressure filters. Cut-away views and sizing tables are included.—Graver Water Conditioning Co.

296*R*

Prestressed Concrete Tanks—Bulletin T-15. A 4-page bulletin on the design and use of prestressed concrete tanks for water supply, sewage treatment, processing applications and containment vessels.—The Preload Company, Inc.

297*R*

Process Package Plants—Bulletin discusses the small package sewage treatment plant that combines aeration, reaeration, settling and aerobic sludge treatment—Walker Process Equipment, Inc.

298*R*

Proportioning Pump—Bulletin 1260-2 & 1260-3 describes an automatic and proportioning chemical feeder, the Chem-O-Feeder which utilizes water from the main itself and which will feed disinfecting solution in proportion to variable flow in the main.—Proportioneers, Inc.

299*R*

Pump Control—Bulletin describes a stepless variable speed flow control for sewage and water pumps. Design construction and operating costs savings and advantages of the Flomatcher system (wound rotor motor and water rheostat) are discussed. Includes pictures of typical installations.—General Services Co.

300*R*

Pump Controllers—Bulletin 128-A is complete with specifications, drawings, sales features and engineering data describing the new "Chicago" Sealtrode Sealed Electrode Floatless Pump Controller.—Chicago Pump Co.

301*R*

Pump Controllers—This bulletin describes purged air and static pump controllers, and gives the different applications for each type. Controllers are suitable for both sewage and clear water.—Healy-Ruff Company.

302*R*

Pumping Stations—"The Application and Design of Prefabricated Pumping Stations" is a manual containing general design information, specifications, drawings and pictures of the Z-F Prefabricated Pumping Station.—Zimmer & Francescon

303*R*

Pump, Sump—Bulletin SP-56 describes a self-contained air motor driven portable sump pump for removing clean or dirty water, sewage or sludge from cellars, excavations, ditches, trenches and settling basins.—Schramm, Inc.

304*R*

Pumps—A series of 4 bulletins cover the complete line of "American" double-suction, split-case, single-stage, two-stage, end suction, axial flow, sludge and deep well turbine pumps.—American Well Works.

305*R*

Pumps—bladeless sewage and trash. Bulletin 5400K—Covers horizontal and vertical bladeless sewage and trash pumps. Diagrams, dimensions, selection tables and performance curves shown.—Fairbanks, Morse & Co.

306*R*

Pumps—centrifugal split case single stage, Bulletin 5874-4, describes these pumps as particularly recommended for municipalities to operate at high speeds against heads which generally require pumps of two stage type.—Fairbanks, Morse & Co.

307*R*

Pumps—A complete line of self-priming centrifugals, sewage and sludge pumps. Bulletins and specifications available.—The Gorman-Rupp Co.

308*R*

Pumps, Axial and Mixed Flow—Bulletin G-100 includes construction and design details, typical installations, and suggested station arrangements. Bulletin F-102 covers Mixed Flow Volute Type pumps.—C. H. Wheeler Mfg. Co.

309*R*

Pumps-Centrifugal—Bulletin carries comprehensive operating data on ACAP pump for handling liquids or hygroscopic solids in suspension under variable capacity and head requirements.—Allis-Chalmers Mfg. Co.

310*R*

Pumps, Deep Well Vertical Turbine—This bulletin, in color, shows a cross-section of the Layne Vertical Turbine pump and applications for it. Both the water and oil lubricated pump bulletins available.—Layne & Bowler, Inc.

311*R*

Pumps, Freflo—A 12 page bulletin covering horizontal and vertical Freflo pumps for handling sewage and industrial wastes. It contains rating curves for 18 pump models. Also included are charts for selection of shafting for use with vertical pumps. Complete dimension data are given for all pump models.—Worthington Corp.

312*R*

Pumps, High Head—Bulletin A-155 describes and illustrates horizontally split case double suction pumps for medium and high head service. Cross Section drawings and construction details are included.—C. H. Wheeler Mfg. Co.

313*R*

Pumps, Multi-Stage—Multi-stage, vertically split case, single suction pumps are described in catalog B-100. Cut-away drawings, construction features and performance curves are included.—C. H. Wheeler Manufacturing Co.

314*R*

Pumps, Non-Clog, Sewage—Bulletin No. 500 contains detailed cross section drawing and information on vertical, close-coupled, "Non-Clog" sewage pump for factory-built sewage pump stations.—Smith & Loveless, Inc.

315*R*

Pumps, Sewage—Horizontal and vertical non-clog pumps for pumping unscreened sewage are illustrated in two bulletins. Construction features, cross section drawings and performance data are included; also suggested methods of mounting vertical pumps and motors.—C. H. Wheeler Manufacturing Co.

316*R*

Pumps, Sewage—Sewage and Sludge Pumps—Both vertical and horizontal dry-pit centrifugals, for capacities to 24,000 g.p.m., sizes from 3" to 24", are described in series catalogs. Submersible and Vertical Submerged Units also available.—Yeomans Brothers Company.

317*R*

Pumps, Sewage and Sludge—The company has a series of bulletins giving data, design features, and specification information on sewage and sludge pumps.—Chicago Pump Co.

318*R*

Pumps, Sewage and Sludge—Bulletin No. KSP-2 a 4 page, 2 color description of Komline-Sanderson dual-valve plunger and diagram pumps, with illustrations and plunger pump selection chart.—Komline Sanderson Engineering Corp.

319*R*

Pumps, Submersible—Bulletin 97 describes in detail a new Immersipump Submersible non-clog sewage and Sump Pump.—Chicago Pump Co.

320*R*

Pumps, Sump—Bulletin 8-SP-11 describes "High & Dry" Sump Pumps for home basements and industry use.—The Gorman-Rupp Co.

321*R*

Pumps, Sump—General service and non-clog sump pumps are described and illustrated in two bulletins which include cutaway drawings, construction features, performance, data and sizes and accessory equipment.—C. H. Wheeler Manufacturing Co.

322*R*

Pumps, Two-Stage—DMD two-stage centrifugal pumps for high head service are described in Bulletin C-1054, which includes cross section and outline drawings and dimensions.—C. H. Wheeler Manufacturing Co.

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323R

Rate Controllers—Bulletins 600-G6A & 600-G6B on filter effluent or back wash rate controllers.—Builders-Providence, Inc.

324R

Recarbonation—Bulletins 1300 and 1310 outline the story of recarbonation and its use in stabilizing lime-softened waters.—Infilco, Incorporated

325R

Receiver-Recorder & Controller—Product specification E12-5 illustrates how four pneumatically transmitted variables may be continuously recorded, in any combination, in the same case by use of plug-in receivers and controllers. Sealed capillary inking system operates for one year without refilling.—Bailey Meter Company

326R

Recorder-Totalizer—a 4 page bulletin describing the proper and efficient applications of recorder-totalizers—Standard Instrument Corp.

327R

Rectangular Clarifier—The "Streamline" is a drag type chain unit available with surface skimming and sludge collection, or with sludge collection alone for final tanks. Request Catalog 6751 for complete details. Yeomans Brothers Company.

328R

Registers, Read-o-Matic—Bulletins R2000 and DR135 illustrates water meter registers that take the meter reader out of the house. The Read-o-Matic register can be located up to one half mile away from the water meter.—Badger Meter Mfg. Co.

329R

Regulators, Sewage Gas—This bulletin presents data on Rockwell's complete line of sewage gas regulators, with inlet pressures above and below 5 psi.—Rockwell Manufacturing Co.

330R

Remote Registering Systems—Bulletin P15, Eighth Edition illustrates and describes Position Motor Type Remote Registering Systems for remote, graphic or visual registration of water levels, gate positions or other moving elements. A variety of self synchronizing motor type transmitters, indicators and recorders are described.—Leupold and Stevens Instruments, Inc.

331R

Ring-Tite Fire-Hydrants—This bulletin illustrates and describes the line of fire hydrants and gate valves with Ring-tite connecting joints made by the company. A. P. Smith Mfg. Co.

332R

Rotagrator® screen and comminutor for faster, more complete comminution with advantage of straight channel installation. Extremely rugged construction for long life. Handle most materials in a single pass. Over-sized solids automatically reprocessed until properly comminuted. Full range of sizes. Bulletin 5150-A—Infilco, Incorporated

333R

Rotary Distributors—Bulletin #5452 gives a brief description of the new, non-clogging, sealess, "Gard" rotary distributor for trickling filters.—General Filter Co.

334R

Rotary Sludge Dryers—This 4-page bulletin discusses and illustrates the Standard Hersey drying system for odor free sewage-sludge drying. Keyed photographs explain construction features.—Standard Steel Corp.

335R

Rotobelt—The Eimco Rotobelt vacuum filter removes filter medium from drum every filter cycle, for cake discharge and washing of medium. A woven stainless steel flexible medium assists sludge cake removal. The Eimco Corp.

336R

Screening Equipment—This technical bulletin describes mechanically cleaned bar screen and grinder designed for a wide range of channel widths and settings with grinder attached to sorting tray, returning shredded screenings to sewage flow.—American Well Works.

337R

Screening Equipment—Catalog outlines traveling water screens for positive removal of floating debris and suspended matter from power stations and water treatment plant influent. Standard basket widths are 2′ to 10′ in 6″ increments.—Jeffrey Mfg. Co.

338R

Screening Equipment—Booklet 2587 illustrates and discusses Link-Belt's line of screening equipment for water, sewage and industrial waste. Dimension drawings and specifications are included.—Link-Belt Co.

339R

Seals for Flanges—Technical bulletin describing unique Gask-O-Seals for sealing ASA-API flanges. Seals are reuseable, eliminate cleaning or resurfacing of flange faces, do not wear due to pulse or vibration. Seals to 15,000 PSI or high vacuum.—Parker Seal Co., Div. of Parker-Hannifin Corp.

340R

Service Boxes—Catalog and descriptive literature on special and standard boxes available.—Opelika Foundry Co., Inc.

341R

Sewage Ejector—A new series of bulletins describes in detail "Chicago's" completely new FLUSH KLEEN Clog Proof Sewage Pumps—with By-Pass inflow fittings, new FLO-THRU strainer etc.—Chicago Pump Co.

342R

Sewage Ejector Lift Stations—Complete 100-page manual on factory-built sewage lift stations. Contains bulletins, selection charts, diagrams and installation data on the "Way-O-Matic", "Mon-O-Ject" and "Du-O-Ject". Also features sewage pump station information.—Smith & Loveless, Inc.

343R

Sewage Ejector Pneumatic—Catalog No. KSM-2, a 14 page, 2 color brochure, complete with illustrations, layout diaphragms, dimension tables, compressor motor selection tables and description of the Komline-Sanderson Pneumatic Sewage Ejector Systems. Covers simplex and duplex units, pneumatically and electrode controlled.—Komline-Sanderson Engineering Corp.

344R

Sewage Ejector System, Pneumatic—12-page 2 color booklet describes the Blackburn-Smith Pneumatic Sewage Ejector that can be operated by either a mechanical float and electric float switch, a mechanical float and pneumatically controlled air valves, or electrode controls. Performance charts photographs and installation diagrams are also included.—Blackburn-Smith Mfg. Co., Inc.

345R

Sewage Lift Stations—A 100-page Engineering Data Manual on factory-built sewage lift stations. Contains design notes, selection charts, drawings and specifications on stations of from 30 to 4500 GPM.—Smith & Loveless, Inc.

346R

Sewage Plant—Primary Sewage Treatment Plant—The Spirahoff® combines primary settling and sludge digestion in a single structure. Specifications and detailed drawings in 8-page catalog.—Yeomans Bros. Company.

347R

Sewage Plant Design Guides—An eight page pamphlet summarizing the basic criteria used by state water pollution control agencies for reviewing sewage treatment plant plans. The basic criteria tabulated is for each of the various treatment units, including screening devices, sedimentation basins, digestors, filters and activated sludge tanks. It also includes a handy tabulation of the water pollution control agencies and their addresses for all states except Alaska and Hawaii.—Portland Cement Assn.

348R

Sewage Pump Station—Complete data manual on factory-built sewage pump stations, proved by over 1,000 installations. Contains bulletins, selection charts, diagrams, installation data and specifications for pump-type or pneumatic ejector lift stations. Feature bulletin appears in this issue.—Smith & Loveless, Inc.

349R

Sewage Treatment—Bulletin 35-D describes equipment available for primary and secondary clarification, sludge thickening and digestion.—Hardinge Co., Inc.

350R

Sewage Treatment—A 64-page catalog covering Jeffrey equipment for the treatment of sewage, water and industrial waste. It is profusely illustrated with installation views and line drawings.—The Jeffrey Mfg. Co.

351R

Sewage Treatment—A 16-page Engineering Data Manual on factory-built Sewage Treatment Plants. Contains de-

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sign note, selection charts, drawings and specification on plants with capacities up to 14,000 G. P. D.—Smith & Loveless, Inc.

352R

Sewage Treatment—A series of 6 bulletins gives detailed information on equipment to perform various steps in sewage treatment. Collectors for solids removal, screens, grit removal units, rotary distributors and digester sludge heating units are covered.—Walker Process Equipment Inc.

353R

Sewage Treatment Equipment—4 page bulletin describes the design, operation and advantages of the SpiroVortex system for the complete treatment of sewage.—Dorr-Oliver Inc.

354R

Sewage Treatment Plant—Complete data manual on factory built "Oxigest" sewage treatment plant for small subdivisions, schools, motels and factories. Contains notes on design, engineering data, specifications and installation instructions, plus lists of accessory equipment. Now 27 standard sizes.—Smith & Loveless, Inc.

355R

Sewage and Waste Treatment—Brochure 135A describes in detail Chicago Pump's Ratedaeration Sewage Treatment process to serve 20 to 5,000 people.—Chicago Pump Co.

356R

Sewage and Waste Treatment—Bulletin No. 300 is a general catalog of equipment and methods for modern waste treatment—Pacific Flush Tank Co.

357R

Sewer Cleaning—Attractive new brochure describes modern techniques and equipment used in the cleaning and complete restoration of clogged sewers of any size or location. Complete contracting service and various methods used to effect maximum pipe efficiency are graphically illustrated.—National Power Rodding Corp.

358R

Sewer Cleaning—a series of 6 bulletin cards which discuss the new way to solve problems of sewer cleaning as practiced by various cities using all-power, automatic SEWERKING equipment.—O'Brien Manufacturing Corp.

359R

Sewer Cleaning—A new brochure describes the latest methods and equipment for cleaning of sewers.—Robinson Pipe Cleaning Co.

360R

Sewer Cleaning Chemical—Illustrated Technical Bulletins available describing Cloroben. A sanitation chemical that dissolves grease and slime accumulations. Also describes a preventive maintenance program.—Cloroben Chemical Corporation

361R

Sewer Lining, Plastic—This bulletin describes T-Lock Amer-Plate, a continuous plastic sewer lining to prevent hydrogen sulfide corrosion. It shows how the T-shaped ribs lock the sheet into the pipe when the concrete is poured.—Amercoat Corp.

362R

Sewer Main Cleaning—Attractive new catalog portrays new Ace Method of power-cleaning sewer mains. Full capacity restored at maximum speed and efficiency with latest mobile equipment designed and engineered for every type job. True action pictures with actual case histories tell complete story in dramatic fashion.—Ace Pipe Cleaning, Inc.

363R

Sewer Pipe, Clay—Catalog SE-50 gives a complete summary of shapes and sizes of clay sewer pipe and supplementary clay products.—Natco Corp.

364R

Sewer Pipe, Plastic—Called "Chem-Weld", this plastic drain pipe is rootproof, durable, and unaffected by acids or alkalis. It fits other types of connecting pipe lines, can be cut with ordinary hand saw. Joints are made with a chemical cement that fuses pipe to coupling. Available in 10, 20 and 30 ft. lengths.—Southwestern Plastic Pipe Co.

365R

Sewer Valves—Brochure covering construction and operation of Crispin Sewer Valves designed to eliminate and control air in sewage force mains.—Multiplex Mfg. Co.

366R

Sewers Cleaned—Modern efficient sewer cleaning process dramatically described in attractive new brochure. Visual proof how clogged sewers of every size and description are restored to full-flow capacity at a fraction of the time and cost ever before possible. Patented machinery and efficient method are outlined in easy to understand language.—National Power Rodding Corp.

367R

Silica (Activated) Feeder—Catalog 60.110 gives description, design features, operating instructions and technical information on the series A-637 WT Silactor, a device for the continuous production and application of chlorine activated silica.—Wallace & Tiernan, Inc.

368R

Silica Activator and Feeder—Bulletin 63-M1 describes equipment designed for the continuous activation and feeding of sodium silicate. The unit features sequence starting, automatic rinse, antigel interlock and variation of aging concentration and aging time.—Omega Machine Co.

369R

Single Stage Centrifugal Pumps—This 4-page bulletin discusses the single stage volute pumps for water works, circulation, drainage and general service.—Worthington Corp.

370R

Single Stage Split Case Pump—4 page bulletin No. 1600 describes Type U-VBM Vertical Non-clog, Ball bearing Centrifugal Pumps for handling sewage and liquids containing solids.—The Weinman Pump Mfg. Co.

371R

Siphons for Sand Filters—This bulletin provides curves for determining rates of siphons discharging into open troughs. Sand filter design for smaller plants is discussed along with piping layouts for the types of siphons available.—Pacific Flush Tank Co.

372R

Sleeves and Valves, Cutting-In—It is easy to install more valves on existing pipe lines, for better control, by using these Mechanical Joint Cutting-In Sleeves and Valves. Suggestions on how to install. Circular No. 20.—M&H Valve and Fittings Company.

373R

Sludge Collectors—Bulletin 315-61 highlights Rex conveyor sludge collectors and appurtenances. Information is general in nature, and is intended primarily to illustrate the diversity and quality of these collectors.—Chain Belt Co.

374R

Sludge Collectors—Descriptive bulletin showing self-propelled traveling bridge type sludge scraper for rectangular settling tanks; unit has no moving maintenance parts immersed in sewage.—Komline-Sanderson Engr. Corp.

375R

Sludge Digesters—Two types, a semi-dome roof for large plants and an I-beam roof for small plants, both with scum breakers and sludge concentration, are described in an 8-page catalog.—Yeomans Brothers Company.

376R

Sludge Digestion—Bulletin 35-D describes digester that prevents scum accumulation and insures uniform gas production.—Hardinge Company, Incorporated.

377R

Sludge Digestion—In addition to bulletins 332 and 235 on floating covers and sludge heat exchangers, P. F. T. has available bulletins 236 and 137 covering floating cover position indicators and gauge boards.—Pacific Flush Tank Co.

378R

Sludge Digestion Tanks—Bulletin T-20. A two page Bulletin on prestressed concrete tanks for sludge digestion, clarifiers, flocculators and thickeners.—The Preload Company, Inc.

379R

Sludge Disintegrator—Literature describes the increasing popularity of sewage sludge as a soil conditioner.—Royer Foundry & Machine Co.

380R

Sludge Drying and Incineration—Bulletin FD-57 covers the C-E Raymond System of Sludge Drying and Incineration. It briefly outlines the problem of sewage disposal and shows why heat drying is regarded as an ideal solution.

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Diagrams and photographs are also included.—Combustion Engineering Inc.

381*R*

Sludge Line Cleaner—Bulletin describes heavy duty grease cleaner for removing grease deposits from sludge lines.—Fine Organics.

382*R*

Sludge Removal—Bulletin 253B describes "American" positive flight conveyors, circular clarifiers, and sludge control valves.—American Well Works.

383*R*

Sludge Removal—Rex Unitube Tow-Bro for removal of light, tricky sludges is covered in this bulletin. New, improved header design is introduced.—Chain Belt Co.

384*R*

Slurry Feeder—This catalog briefly describes the design, operation and application of this positive displacement slurry pump for feeding lime, diatomaceous earth and similar slurries.—Precision Chemical Pump Corp.

385*R*

Spiractor—Bulletin (2384) presents the Permutit Spiractor for softening and alkalinity reduction. This compact cold lime-soda softener is recommended for the treatment of clear, hard water. The Spiractor is small in size and flexible in operation. No sludge handling necessary.—Permutit Co.

386*R*

Square Bottom Valve—This bulletin gives complete descriptive information on the Rensselaer square bottom valve.—Ludlow Valve Mfg. Co., Inc.

387*R*

Squirrel-Cage Motors—This bulletin describes the company's large two-pole squirrel-cage induction motors, 900 hp and larger, designed to meet requirements of today's high speed drives.—Allis-Chalmers Mfg. Co.

388*R*

Standard Sewage Siphons—This bulletin describes the P. F. T. standard sewage siphon for small disposal plants for use with small sand filters, sub-surface tile fields and either septic tanks or small Imhoff tanks. Standard dimensions and capacity of siphons are included.—Pacific Flush Tank Co.

389*R*

Steam Cleaner—Booklet discusses the Hypressure Jenny steam cleaner for cleaning and deodorizing bar screens, grit and scum loading pits, etc.—Homestead Valve Mfg. Co.

390*R*

Steel and Alloy Fabrication and Erection—A compact 4-page folder suggests the many uses of steel and alloy plate, as fabricated and erected by Graver. Fully illustrated, it offers examples of the many products and services provided by Graver craftsmen on a custom basis. Although Graver boasts a 102-year history, its techniques are modern and forward-looking, as its work on geodesic domes and atomic installation attests.—Graver Tank & Mfg. Co., Div.—Union Tank Car Company.

391*R*

Steel Pipe—Five booklets describe the fabrication and installation of interesting steel water lines in a number of diameters. Booklet 503 describes a 14-ft flow line; Booklet 397 describes a 96-in. industrial water line; Booklet 402 describes the 72-in. Ramapo force main in New Jersey; Booklet 431 describes 42-in. pipe at Lancaster, Pa.; and Booklet 408 describes a 36-in. and 30-in. pumping main at Reading, Pa.—Bethlehem Steel Co.

392*R*

Steel Reservoirs and Standpipes—A 24-page booklet on Horton Steel Reservoirs and Standpipes. Illustrations show installations from 50,000 to 10,000,000 gal. capacity with cone, umbrella, or ellipsoidal roofs and ornamental structures with special architectural features. Also included are: table of standard capacities, information on foundations, advantage of pickling and painting, and data on the use of suction tank for fire protection.—Chicago Bridge & Iron Co.

393*R*

Steel Reservoirs and Standpipes—A brochure on flat bottom water storage that discusses the uses of steel tanks with photos showing various roof types, ornamental structural features, and various sizes. A list of standard reservoir dimensions is also included.—Pittsburgh-Des Moines Steel Co.

394*R*

Steel Tanks—Types of Construction, sizes and designs are presented in the booklet "Only Steel Gives You Tanks Built to AWWA Standard"—Steel Plate Fabricators Assn.

395*R*

Storage Bins—Bulletin Seg-13 contains details and illustrations on circular storage bins of Natco Segmentile, which are adaptable for sand, ash and coal bins, as well as other types of bulk storage.—Natco Corp.

396*R*

Strainers, Liquid—Bulletin describes the company's line of self-cleaning liquid strainers.—Golden-Anderson Valve Specialty Co.

397*R*

Supernatant Corrector—How the Presaire method reduces B.O.D. by satisfying a goodly portion of the I.O.D. is detailed in a 4-page engineering bulletin.—Yeomans Brothers Company.

398*R*

Supervisory and Remote Control—Bulletin 240-P2A describes unlimited number of control or advisory functions from central control panel over widely spread system using sequencing transmission system. Other bulletins describe Chronoflo telemetering, "Synchro-Scan" pneumatic and electrical transmission and control of level, pressure, pumps, etc.—Builders Providence, Inc.

399*R*

Surge and Hammer Control—Bulletin 200 illustrates and describes the company's Controlled Closing air valve that was designed for the protection of pipe lines against surge built-up pressures or water hammer.—Simplex Valve & Meter Co.

400*R*

Surge & Water Hammer Control—A 28 page booklet describing the construction of Crispin automatic air valves available for control of air problems in lines handling liquids.—Multiplex Mfg. Co.

401*R*

Swimming Pool Chemicals—24-page booklet is a guide to simplified bacteria control in private pools, public pools, camps, hotels.—Pennsalt Chemicals Corp., Phila., Pa.

402*R*

Swimming Pool Equipment—Bulletin (2157) outlines purification and recirculation equipment necessary for the modern pool. Tables are provided for correctly sizing equipment and pools.—Permutit Co.

403*R*

Swimming Pool Filters—New data manual on quality S & L filtration equipment for swimming pools. Contains diagrams, selection charts and list of installations.—Smith & Loveless, Inc.

404*R*

Swimming Pool operation and Disinfection—(Bulletin P-1009)—describes general operations, filtration and sterilization methods for commercial pools. Pennsalt of Washington Division, Pennsalt Chemicals Corp., Tacoma, Wash.

405*R*

Swing-Type Check Valves—This bulletin illustrates and describes the Rensselaer swing type check valves and the clear way, quiet closing check valve.—Ludlow Valve Mafg. Co., Inc.

406*R*

Tanks—This 20-page booklet, now reprinted for a third time, presents the many uses of Graver Standard Storage Tanks. The booklet has proved popular and useful, since it provides information on tankage for water, fuel, oil asphalt, dry materials and a host of other products. Tables of sizes, weights and accessories make the booklet worth keeping for reference.—Graver Tank & Mfg. Co. Div.—Union Tank Car Company.

407*R*

Tapping Sleeves—Bulletin D illustrates and describes Rensselaer tapping sleeves and valve.—Ludlow Valve Mfg. Co., Inc.

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408*R*

Tapping Sleeves—Circular #12 illustrates a complete line of tapping sleeves and tapping valves either with hub or mechanical joint ends.—M&H Valve and Fittings Company.

409*R*

Tapping Sleeves—This bulletin describes and illustrates the complete line of mechanical joint tapping sleeves and valves manufactured by the company. —A. P. Smith Mfg. Co.

410*R*

Tapping Valves & Sleeves Under Pressure—This bulletin describes the Eddy tapping valves and sleeves, for tapping water mains under pressure.—Eddy Valve Co.

411*R*

Tapping Valves & Sleeves—This bulletin illustrates and describes Iowa tapping valves and sleeves, and repair sleeves for water mains.—Iowa Valve Co.

412*R*

Taste and Odor Control—This booklet describes the use of Aqua Nuchar activated carbon in water purification.—West Virginia Pulp & Paper Co.

413*R*

Telemetering—Transmission and reception of data on flow, liquid level, pressure, temperature, etc., from any distance over a single two-wire circuit is shown in this bulletin 230-P4.—Builders-Providence, Inc.

414*R*

Thickeners—Eimco-Process Thickeners are built in several basic types and available with a number of custom adaptations for special sedimentation problems. Bulletin SM-1004.—The Eimco Corp.

415*R*

Thickeners—Bulletin 31-E describes the "Auto-Raise" thickener mechanism for both small and large heavy duty settling tank operations, and waste treatment applications of the rectangular type clarifier.—Hardinge Company, Incorporated.

416*R*

T-Lock Amer-Plate—This brochure describes T-Lock Amer-Plate, a continuous plastic sewer lining. "T-Lock" refers to the T-shaped ribs which project from the back of the sheet and lock the sheet into the pipe or structure when the concrete is cast.—Amercoat Corporation.

417*R*

Trash Racks—Bull. 02B9207 describes the Leonard Trash Rack Rakes with dimensions, specifications and typical arrangements.—Allis-Chalmers Mfg. Co.

418*R*

Trenchers and Backfillers—A 2-color booklet describing the features and listing specifications of the models 92 and 95 "Baby Diggers," the models 110, 140, 240, and 320 standard trenchers, and models 80W and 190 backfillers. Photographs of each piece of equipment are shown along with illustrations of the equipment in operation.—Cleveland Trencher Co.

419*R*

Trenching & Construction Equipment—Thirteen bulletins on tractors, crawlers, trenchers and loaders for installation of water mains or sewers.—Oliver Corp.

420*R*

Trickling Filter Distributor—This technical bulletin describes reaction and positive drive types, equipped with patented dual oil seal which will withstand at least 10' of water pressures.—American Well Works.

421*R*

Trickling Filter Distributor—Bulletin 313A covers spreader jets for rotary distributors for trickling filters.—Pacific Flush Tank Co.

422*R*

Trickling Filter Distributor—This bulletin describes the "Sy-No-Seal" reaction type rotary distributor which contains no seal between the stationary center column and the rotating distribution arms.—Smith & Loveless, Inc.

423*R*

Trickling Filter Distributors—A complete line of reaction type distributors with mercury or mechanical seals, and choice of nozzle is described in a 12-page catalog.—Yeomans Brothers Company.

424*R*

Trickling Filter Manual—This 24-page engineers' manual suggests arrangements for plant components for both primary and complete treatment using the Spirahoff for primary settling and sludge digestion. Complete data, including recommended sizes and specifications.—Yeomans Bros. Company.

425*R*

Tyton Joint Pipe—This booklet presents the U. S. centrifugally cast "Tyton joint" pipe for water and sewage. This new joint pipe is simple, sturdy and tight. Illustrations show details of joint and method of assembly.— U. S. Pipe & Foundry Co.

426*R*

Underdrain—Data on Graver's patented underdrain for rapid sand filters is contained in Bulletin M-100. Showing detail of construction and specifications, the Bulletin includes a pressure drop curve.—Graver Water Conditioning Co.

427*R*

Upflow Coagulation Unit—This bulletin describes the operation advantages and design features of the Permutit Precipitator and contains flow diagrams, installation photos and specifications.—The Permutit Co.

428*R*

Vacuum Breakers—Brochure on Crispin air and vacuum valves designed to break the vacuum during the emptying operation of a pipe line or tank.—Multiplex Mfg. Co.

429*R*

Vacuum Filter—16 page brochure on the Coil-filter, the sludge vacuum filter featuring permanent type filter media, non-clogging operation, constant output. Standard sizes of equipment are listed. Bulletin No. 106—Komline Sanderson Engineering Corp.

430*R*

Vacuum Pumps—Rotary positive pressure vacuum pumps featured in bulletins S65-C and S59-G, both standard and heavy duty series, vertical and horizontal designs.—Sutorbilt Corp.

431*R*

Valve Boxes—Descriptive literature and catalog available.—Opelika Foundry Co., Inc.

432*R*

Valve and Meter Boxes—Bulletin 2000 on Valve, Roadway, Service and Meter Boxes along with Manhole Frames and Covers.—Alabama Pipe Co.

433*R*

Valve Operator—Catalog V-200 illustrates and describes the Valvmatic actuator conversion unit which changes hand-operated valves to automatic operation without removing valves from the line of disturbing piping. The six easy steps for installing Valvmatic are also shown.—C. H. Wheeler Manufacturing Co.

434*R*

Valve Operators—Product Specification P81-1 shows how the regulation of fluid flow may be improved by use of a characterized valve operator. Butterfly valves, feeders, and other final control elements may be operated on a straight-line flow basis—Bailey Meter Company.

435*R*

Valve Plug—Literature describes plug valve with a facing of Hycar American Rubber—DeZurik Corp.

436*R*

Valves—A folder discussing bronze and iron valves, gate, globe, angle, check and meter valves, sluice gates, pivot valves and motor unit.—Chapman Valve Manufacturing Co.

437*R*

Valves, Air Release—A 28 page catalog offering complete information on the many types of Crispin automatic air valves preferred by works engineers for over 45 years for positive air control. Multiplex Mfg. Co.

438*R*

Valves, Altitude and Level—Bulletin W-4-A describes altitude valves and modifications of water level control valves.—Golden-Anderson Valve Specialty Co.

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439*R*

Valves, AWWA—Four page illustrated circular describing A.W.W.A. Gate Valves, Class C, NRS or OS & Y. These are double disc gate valves with conventional packing or O-ring seal plate, in sizes 2"-42", Circular No. 14 —M & H Valve and Fittings Co.

440*R*

Valves, Ball—New ACF Non-lubricated ball valves are completely described in catalog 1000. Valves available in semi-steel and carbon steel with full-bore conduit, leakproof, two-way seal and other outstanding features.—W-K-M division of ACF Industries, Inc.

441*R*

Valves, Bronze—Circular AD-2285 gives technical data on 200 lb. bronze gates. Valves feature rugged, cylindrical body design with rolled-in Exelloy seat rings. —Crane Co.

442*R*

Valves, Butterfly—Bulletins 650-L1B, 650.20-1 and 650.20.2 on tight-closing rubber seated butterfly valves built to AWWA specifications.—Builders-Providence, Inc.

443*R*

Valves, Butterfly—Bulletin No. 5708 gives complete description of the Darling-Pelton Rubber Seated Butterfly Valves.—Darling Valve & Mfg. Co.

444*R*

Valves, Butterfly—This 2-color brochure describes Leopold rubber seated butterfly valves. Complete details on the construction features and valve assembly are included.—F. B. Leopold Co., Inc.

445*R*

Valves, Butterfly—A manual on rubber seated butterfly valves containing complete information including data on valve sizing, operator selection, theory of valve design, etc.—Henry Pratt Co. Inc.

446*R*

Valves, Butterfly—Bulletin No. 581 gives complete data on rubber-seated butterfly valves built to AWWA specifications. —W. S. Rockwell Company

447*R*

Valves, Butterfly—Bulletin No. 582 gives complete data on standard 25-, 50- and 125-lb. class butterfly valves, metal-to-metal seated and rubber seated.—W. S. Rockwell Company

448*R*

Valves, Check—Bulletin #W-1 illustrates and describes cushioned type swing check valves.—Golden-Anderson Valve Specialty Co.

449*R*

Valves, Check—Circular #18 illustrates and describes a complete line of swing check valves in sizes up to 24", available with outside lever and weight or outside spring and lever arrangement. Can be supplied with flanged or mechanical joint ends. This line features full-way opening in all sizes.—M&H Valve and Fittings Company.

450*R*

Valves, Chlorine Handling—Circular AD-1976 gives data on globe and angle valves designed for control of water-free chlorine gas or liquid.—Crane Co.

451*R*

Valves, Cushioned—Bulletin describes the company's cushioned valves in action.—Golden-Anderson Valve Specialty Co.

452*R*

Valves, Cut-in—A 4-page bulletin tells how these cushioned emergency cut-in valves automatically open to emergency water supply.—Golden-Anderson Valve Specialty Co.

453*R*

Valves, Diaphragm—8-page Bulletin gives complete information on the Grinnell-Saunders diaphragm valve.—Grinnell Co. Inc.

454*R*

Valves, Howell-Bunger—16 page bulletin 02B9206 tells how these valves operate for the easy regulation and control of water under free discharge for high and low heads.—Allis-Chalmers Mfg. Co.

455*R*

Valves & Hydrants—Catalog 52 describes and illustrates complete line of gate valves, hydrants, pipe fittings, and accessories for construction of water works systems, sewage plants, filter plants and industrial uses.—M & H Valve & Fittings Co.

456*R*

Valves, Low Pressure—Circular #16 describes a full range of low pressure gate valves available in either double disc or solid wedge design and for 50 #or 100# water working pressure. Size range 10" to 42".—M&H Valve and Fittings Co.

457*R*

Valves, Lubricated Plug—This bulletin describes and illustrates the utility of the Rockwell-Nordstrom lubricant-sealed plug valves in sewage treatment plants.—Rockwell Manufacturing Co.

458*R*

Valves, Plug—This 36-page catalog contains the complete line of plug valves, discussing eccentric action and other exclusive features of the DeZurik valves. Sizes and other specification are included.—DeZurik Corporation

459*R*

Valves, Plug—Book 39-2 describes cam-sealed quarter-turn plug valves. Book 39-3 shows lever-sealed quarter-turn plug valves with built-in means of moving plug under all conditions. Book 39-5 describes lubricated plug valves in straightway, 3-way, 4-way and multiple port types.—Homestead Valve Mfg. Co.

460*R*

Valves, Plug—Catalog 1100 covers ACF carbon steel lubricated plug valves, ASA 150 and ASA 300, including straightway, venturi and multiport types.—W-K-M division of ACF Industries, Inc.

461*R*

Valves, Water Works—Bulletin No. WW-58 gives complete information on many types of curb stops, corporation stops, gooseneck meter stops, service boxes and couplings that are popular in the water works industry.—A. Y. McDonald Mfg. Co.

462*R*

Vertical Turbine Pumps—This bulletin, diagrammed in color, discusses water lubricated vertical turbine pumps in capacities of from 15 to 15,000 GPM.—Worthington Corp.

463*R*

Vitrified Clay Pipe—A series of engineering Handbooks on Vitrified Clay Pipe.—National Clay Pipe Mfgr. Inc.

464*R*

Vorti® Mixers and Vorti-Floc®—coagulators provide the advantages of low power consumption, no underwater bearings and effective mixing and floc formation. May be used in rectangular, square or round basins. Bulletin 730-5430—Infilco Incorporated

465*R*

Walking Beam Flocculators—A question and answer booklet on Walking Beam Flocculating Equipment.—Stuart Corp.

466*R*

Water Clarification—Hagan Coagulant Aids Nos. 7, 11 and 18, used to improve floc formation in clarifying and softening municipal, industrial and oil field water systems, are described in this bulletin.—Hagan Chemical & Controls, Inc.

467*R*

Water Conditioning Plant Package—This bulletin describes the operation of equipment which makes up the package water conditioning plant. This package plant is available in 8 standard sizes ranging from 500 to 3300 gph.—The Permutit Co.

468*R*

Water Level Recorder—Bulletin 24, Tenth Edition contains eight pages of illustrations and descriptive data on the Stevens Type F Water Level Recorder. Applications data for this extremely sensitive and accurate, yet inexpensive recorder, is included. Also, described is the Type FM Recorder and Stevens porcelain enameled iron gages.—Leupold and Stevens Instruments, Inc.

469*R*

Water Main Cleaning—Bulletin describes the complete service for the cleaning and restoration of clogged wa-

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ter mains. New techniques developed provide the maximum in efficiency and economy.—National Power Rodding Corp.

470*R*

Water Main Cleaning—New literature describes the latest most up-to-date techniques in the cleaning of water mains of any size.—Robinson Pipe Cleaning Co.

471*R*

Water Mains Restored—The story of clogged and abandoned water mains returned to normal use after patented cleaning process applied. New 2-color brochure completely describes exclusive patented equipment used to restore water pipes to a guaranteed 95% of normal capacity, at a fraction of the cost of new pipe installation—National Power Rodding Corp.

472*R*

Waterproofing—20-page specification guide for the Thoro System of waterproofing, protective and corrective treatments for masonry—concrete, block, stucco, tile, stone—Standard Dry Wall Products, Inc.

473*R*

Water Re-Use—Technical Reprint T-129 discusses the treatment of sewage plant effluent for process and boiler feedwater uses. Dealing with a most important subject of water re-use, this paper indicates some of the considerations and details of this type of process.—Graver Water Conditioning Co.

474*R*

Water & Sewage Valves—A 28 page catalog offering complete information on the many types of Crispin air valves for positive air control on water and sewage lines.—Multiplex Mfg. Co.

475*R*

Waterstop, Plastic—Literature describes a new type of polyvinyl plastic labyrinth waterstop that can be installed in a matter of seconds.—Water Seals, Inc.

476*R*

Waterstops, Concrete—Catalog sheet presenting specifications drawings of the labyrinth, flextrip, cellular and dumbbell waterstops.—Water Seals, Inc.

477*R*

Water Treating Plant—Complete in a single package for the treatment of surface or well waters in capacities from 15 to 350 g.p.m. Ideal for small communties, industrial plants or institutions. Bulletin 1870-A—Infilco Incorporated

478*R*

Water Treatment—Reference folder serves as a convenient file on the use of activated silica sol as coagulant aid for treating raw, process and waste waters. Advantages are cited pertinent to improved quality of filter water. Sodium silicate control of corrosion in water lines also is reviewed, together with a list of metals protected.—Philadelphia Quartz Co.

479*R*

Water Treatment Equipment—A general descriptive brochure WC-117 indicating the types of water treatment equipment available from the company.—Graver Water Conditioning Co.

480*R*

Water Treatment Equipment—Catalog describes the FLOCTROL process for efficient clarification of water, sewage or trade wastes. The Jeffrey FLOCTROL is available in two designs; the horizontal design for ultimate operating efficiency for all water treatment plants preceded by rapid mixers. For smaller plants there is the vertical mixer. Controlled flocculation is fully described in this 66-page catalog.—Jeffrey Mfg. Co.

481*R*

Water Treatment Equipment—A new booklet (4433) describes modern water treatment equipment and discusses the methods of selection of equipment for various systems. —The Permutit Co.

482*R*

Water & Waste—This bulletin offers 24-pages of illustrations and description covering the major equipment designed and manufactured by the company for water, waste and sewage treatment.—Walker Process Equipment Inc.

483*R*

Water and Waste-Water Treatment—Bulletin 35-D illustrates and describes equipment used for treatment of water, sewage and trade wastes.—Hardinge Company, Incorporated

484*R*

Water Well Development—Bulletin 234, "Water in Abundance," describes the engineering principles of natural development of water wells in sand and sand-gravel formations through the use of continuous slot well screens.—Edward E. Johnson, Inc.

485*R*

Water Well Testing—Bulletin 1243 discusses methods of measuring water levels in wells during testing and use of various types of equipment in determining quantity of water produced.—Edward E. Johnson, Inc.

486*R*

Waterworks Products—This general bulletin describes miscellaneous Clow products, including cutting-in valves, waterworks sleeves, and other cast iron specials.—James B. Clow & Sons, Inc.

487*R*

Water Works Promotion—A 16 page illustrated booklet titled, "Water—Make Sure You'll Always Have Plenty", is one of the first to detail a complete plan for local support of water system improvements. It shows how responsible citizens can learn from their public officials the needs and plans of their community.—Cast Iron Pipe Research Assn.

488*R*

Well Corrosion—Corrosion and Incrustation in Water wells—bulletin 834 describes the various types of corrosion and incrustation in water wells, means of correction and prevention, and methods of acid-treating water wells.—Edward E. Johnson, Inc.

489*R*

Well Strainers—A new 48-page, catalog describes the self-cleaning V-shaped slot well strainers, and contains information concerning the recommended procedure for well strainer installation, uses, etc.—Cook Well Strainer Co.

490*R*

Well Water Systems—Bulletin 100 illustrates and discusses pumps, drilling, allied services and equipment available from the company.—Layne & Bowler, Inc.

491*R*

Wrenches, Pipe—Form 125 pictures the New Sliding Jaw Wheeler Pipe Wrench. —Wheeler Mfg. Corp.

492*R*

Wrought Iron O.D. Piping—Eight pages highlight wrought iron's durability in large O.D. applications. Included are specific water and sewage service records, recent installations, and an account of the famous Virginia City Pipe line.—A. M. Byers Co.

493*R*

Wrought Iron Sewage Installations—A 30-page bulletin describes numerous applications of wrought iron pipe and plate in sewage treatment and disposal plants of leading American cities. Some unusual design features emphasize wrought iron's versatility in corrosive sewage services.—A. M. Byers Co.

494*R*

Yield of Water Wells—Bulletin 1238 explains the hydraulic principles of water-bearing sand and gravel formations, the effect on yield of water wells and methods of estimating potential yield before a water well is drilled.—Edward E. Johnson, Inc.

495*R*

Zeolite Softening—Bulletin #5763 illustrates and describes the "CR" softeners and how to select the proper size when hardness and flow is known.—General Filter Co.

496*R*

Zeolite Water Softeners—This bulletin WC-408 describes the zeolite exchange water softening process, includes details of equipment design and basic sizing tables.—Graver Water Conditioning Co.

497*R*

Zeolite Water Softeners—This 20-page bulletin details the troubles caused by using hard water and the many economies effected by curing these troubles. The bulletin also contains equipment specifications, operating characteristics, and data on Permutit ion exchange resins.—The Permutit Co.

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ALL COMPANIES LISTED IN **BOLD FACE** TYPE HAVE ADVERTISEMENTS IN THIS ISSUE.

For the Index to the Reference and Data Material, and the Index to Advertisers, See the Rear Section of this Issue.

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D

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Pumps, Self Priming,
Water, Leak, Locating Instruments

Darling Valve & Mfg. Co.
Ft. of Walnut St.
Williamsport, Pa.
B-50-B Fire Hydrants
Floor Stands
Indicator Posts
Sleeves, Tapping
Valves, Air Release and Vacuum Breaking
Valves, Air Relief
Valves, Aluminum
Valves, Bronze
Valves, Butterfly
Valves, Check
Valves, Cylinder Operated
Valves, Gate
Valves, Iron
Valves, Mechanical Joint
Valves, Motor Operated
Valves, Rubber Lined
Valves, Special Alloy
Valves, Steel
Valves, Tapping

Payne Dean & Co.
Clinton, Conn.
Gate Valve Operator

De Zurik Corporation
49 Riverview Rd.
Sartell, Minnesota
Valve Boxes
Valves, Four Way
Valves, Gate
Valves, Hydraulic, Cylinder operated
Valves, Mechanical, Joint
Valves, Motor Operated
Valves, Mud and Plug
Valves, Sludge
Valves, Special Automatic including Remote control

Dixie Tank & Bridge Co.
Box 14
Memphis 1, Tenn.
Tank; Maintenance and Repair

Dorr-Oliver Inc.
Havemeyer Lane
Stamford, Conn.
Aeration Apparatus
Agitators
Clarifiers, Sewage and Water
De-Mineralization Equipment (Water)
Digester Equipment (Sludge)
Distributors (Sewage Filter)
Filter Equipment
Filters Vacuum
Flocculating Equipment
Gas Holders
Grinders, Garbage and Screenings
Grit Chamber Equipment and Grit Washers
Heaters, Digester
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Diaphragm
Pumps, Sewage and Drainage
Pumps, Sludge
Pumps, Vacuum
Screens, Sewage
Slakers
Sludge Collectors
Sludge Disintegrators
Thickeners (Sludge)
Trickling Filter Equipment
Vacuum Filters
Water Softening Equipment

E

Eddy Valve Co.
Waterford, N. Y.
Gates, Shear
Valve Boxes
Valves, Air Relief
Valves, Flap
Valves, Float
Valves, Foot
Valves, Mechanical Joint
Valves, Mud and Plug
Valves, Relief

Eimco Corp.
634 S. 4th St.
Salt Lake City, Utah
Agitators
Chain Collectors
Clarifiers
Cleanable Sight Glass
Diffusers
Digester Mixers
Filters, Vacuum
Flocculators
Flotation Clarifiers
Flotation Thickeners
Gas Purifiers
Grit Separators
Lime Slakers
Oxidators
Rotary Distributors
Rotobelts
Sludge Thickness Controllers
Tractors

Electro Rust Proofing Corp.
30 Main Street
Belleville 9, New Jersey
Cathodic Protective Systems

Ellis & Ford Mfg. Co.
1100 Coolidge Road
Birmingham, Mich.
Pipe Cutting Machines

Engineering Controls, Inc.
328 Paul Brown Bldg.
St. Louis, Mo.
Heat Recovery & Cooling Systems (Vapor Phase)

F

Fairbanks Morse Co.
600 S. Michigan Ave.
Chicago 5, Illinois
Alternators, Electric
Compressors, Rotary
Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines, Gas or Gasoline
Engines, Sludge, Gas
Generators, Electric
Motors, Electric
Pumps, Bladeless, Non-Clog
Pumps, Centrifugal
Pumps, Submersible
Pumps, Turbine

Filtration Equipment Corp.
P. O. Box 1331
Rochester 3, N. Y.
FECO "FRE-FLO" Filter Bottoms
Filter Operating Tables
Filter Wash Troughs
Lighting Surface Wash Baffles
Parshall Flume Liners
Slide Gates and Guides

Fine Organics Inc.
205-225 Main Street
Lodi, N. J.
Activated Carbon
Deodorizing
Sludge Line Cleaner

Fischer & Porter Co.
925 Warminster Road
Hatboro, Pa.
Alarm Signals & Systems
Automation Equipment & Systems
Chlorinators
Chlorine Gas Control Apparatus
Chlorine Gas Recorders
Chlorine Gas Totalizers
Controllers & Regulators
Flow Ratio Systems
Fluorinators
Gauges & Meters
Indicators
Instruments
Laboratory Apparatus & Equipment (glassware)
Manometers, Mercury
Meters & Gauges
Oxidation-Reduction Potential Measurement & Control Apparatus
Panels
Centralized Control
Graphic
Pumps, Metering
Recorders
Rotameters
Specific Gravity Apparatus
Systems, Control
Telemeters
Test Units
Transmitters
Valves
Acid-resistant
Air
Air control
Air operated
Control
Corrosion-resistant
Diaphragm
Flow control
Glass
Motor-operated
Peumatic
Pressure-regulating
Regulator and constant flow
Vaporizers, Chlorine
Water Sterilizers

Fisher Research Laboratory
P. O. Box 640
Palo Alto, Calif.
Pipe Locators

Ford Meter Box Co., Inc.
PO Box 376
Wabash, Ind.
Meter Accessories-Boxes, Housing, Setting
Meter Couplings, Yokes
Meter Testing Equipment
Valve Boxes

Foster Engineering Co.
835 Lehigh Ave.
Union, New Jersey
"Gentile" Flow Tubes
"Foster" Automatic Valves, pressure reducing for air or water
Valves, altitude
Valves, cushioned check
Valves, float operated
Valves, motor operated
Valves, temperature regulating
Valves, vacuum breaker and regulating

Foxboro Co.
298 Neposet Ave.
Foxboro, Mass.
Controllers-Flow, Level Pressure, Temperature,
Electrical Control Equipment
Meters, Flow Tube
Meters, Gas
Operating Tables (Filter)
Orifices
Pitot Tubes
Rate of Flow Controllers
Rate of Flow Recorders
Venturi Tubes
Water Level Controllers
Water Level Recorders

Frontier Chemical Co.
Div. of Union Chemical and Materials Corp.
Wichita, Kansas
Acid Sulfuric and Hydrochloric
Chlorine, Liquid

Fuller Company
Sutorbilt Corp.
2966 E. Victoria Street
Compton, Calif.
Blowers
Gas Pumps
Vacuum Pumps

Fuller Company
Catasauqua, Pa.
(See Sutorbilt Corp.)

G

Gamon Meter Div.
Worthington Corp.
296 South Street
Newark 5, N. J.
Meters, Water (Consumer)

Gar Wood Industries, Inc.
36253 Michigan Ave.
Wayne, Mich.

Ditchers
Trenchers

General American Transportation Corp.
135 S. LaSalle Street
Field Building
Chicago 90, Ill.

Gas Holders
Tanks, Storage

General Filter Co.
923 2nd Street
Ames, Iowa

Agitators
Boiler Feedwater Treatment & Equipment
Carbonators (Recarbonation)
Chemical Feeding & Proportioning Equip.
Clarifiers, Sewage & Water
Controllers Flow, Level, Pressure, Temperature
De-Mineralization Equipment (Water)
Diatomite Filter Septums
Electrical Control Equipment
Filter Equipment
Filter Underdrains, Water
Flocculating Equipment
Gas Diffusers
Indicators, Large Dial Illuminated
Operating Tables (Filter)
Orifices
Rate of Flow Controllers
Rate of Flow Recorders
Sludge Collectors
Tank Linings
Trickling Filter Equipment
Water Softening Equipment
Water Treatment for Scale & Corrosion
Zeolite & Zeolite Softeners

General Services Co.
P.O. Box 612
Corvallis, Oregon

Pumping Rate Control

Glenfield & Kennedy Inc.
706 North Ave.
New Rochelle, New York

Filter Equipment
Strainers-Suction

Golden-Anderson Valve Spec. Co.
1232 Ridge Ave.
Pittsburgh 33, Pa.

Valves, Altitude
Valves, Check
Valves, Cone
Valves, Float
Valves, Motor Operated
Valves, Pressure Reducing
Valves, Relief
Valves, Rubber, Plastic, Glass, Lead
Valves, Special automatic including Remote Control

Gorman-Rupp Co.
305 Bowman Street
Mansfield, Ohio

Pumps, Centrifugal
Pumps, Sewage & Sludge
Pumps, Sump

Graver Tank & Mfg. Co.
4809 Tod Ave.
E. Chicago, Ind.

Bins
Breechings
Elevated Water Tanks
Gas Holders
Pressure Tanks
Pump Suction Tanks
Reservoirs
Stacks
Standpipes
Storage Tanks

Graver Water Conditioning Co.
216 W. 14th Street
New York 11, N. Y.

Activated Carbon
Aeration Apparatus
Agitators
Anthrafilt
Boiler Feedwater Treatment and Equipment
Carbonators (Recarbonating)
Chemical Feeding and Proportioning Equipment
Clarifiers, Sewage and Water
Dechlorinating Equipment and Chemicals
Demineralization Equipment (Water)
Feed Water Heaters
Filters
Filter Equipment
Filter Media
Filter Underdrains, Water
Flocculating Equipment
Grit Chamber Equipment and Grit Washers
Operating Tables
Sludge Collectors
Thickeners (Sludge)
Water Softening Equipment
Zeolite
Zeolite Softeners

Griffin Wheel Company
Griffin Pipe Division
445 N. Sacramento Blvd.
Chicago 12, Ill.

Pipe, Cast Iron

Grinnell Co., Inc.
Providence, R. I.

Brass Goods
Fittings, Tees, Ells
Jointing Compounds, Materials
Joints, Mechanical, Flexible
Nozzles, Spray, Water and Sewage
Orifices
Pipe-Fittings, Lined
Sewer Pipe Joints & Jointing Compounds
Valves, Check
Valves, Chlorine
Valves, Diaphragm
Valves, Hydraulic (Cylinder operated)
Valves, Foot
Valves, Special Automation (Including Remote Control)

H

Hagan Chemicals & Controls, Inc.
Hagan Building
Pittsburgh 30, Pennsylvania

Blending controlling
Chemical feed controlling
Electric measurement transmitting
Filter rate of flow measuring and recording
Flow integrators, local and remote
Flow (measuring, recording, indicating and controlling)
Level (measuring, recording, indicating and controlling)
Loss of head measuring and recording equipment
pH (measuring, recording, indicating and controlling)
Pneumatic measurement transmitting
Pressure (measuring, recording, indicating and controlling)
Primary measuring elements
Temperature (measuring, recording, indicating and controlling)
Valve positioners
Water conditioners

Hamilton Kent Mfg. Co.
427 W. Grant St.
Kent, Ohio

Coatings, Acid and Alkali-Proof
Couplings, Flexible
Joints, Mechanical Flexible
Rubber Packing Gaskets

Hardinge Co., Inc.
240 Arch Street
York, Pa.

Agitators
Castings, Iron, Steel, Alloy Steel
Clarifiers, Sewage and Water
Drying Systems (Sludge)
Filter Equipment
Flocculating Equipment
Sludge Collectors
Thickeners (Sludge)

Healy-Ruff Company
783 Hampden Ave.
St. Paul 4, Minn.

Alternators, Electric
Controllers Flow, Level, Pressure, Temperature
Electrical Control Equipment
Gages (Liquid Level, Pressure Recording)
Indicators, Large Dial Illuminated
Pumping Controls
Water Level Control

Hercules Powder Company, Inc.
Wilmington 99, Delaware

Coating, Protective

Hersey Mfg. Company
P.O. Box 31
Dedham, Mass.

Meter Repair Parts
Meters (Turbine Type)
Meter Testing Equipment
Meters, Water (Consumer)
Testers (Water Meter)
Valves, Check
Valves, Water Meter Special

Hollaender Mfg. Co.
3841 Spring Grove Ave.
Cincinnati, Ohio

Gratings, Floorways, Treads, Railings

Homestead Valve & Mfg. Co.
Box 348
Coraopolis, Pa.

Cocks (Curb Meter, Corp. etc)
Valves, Cone
Valves, Four Way
Valves, Hydraulic Cylinder Operated
Valves, Lubricated Plug
Valves, Motor Operated
Valves, Mud and Plug

Hooker Chemical Corp.
Niagara Falls, New York

Chlorine, Liquid

Hydraulic Development Co.
West Bedford 56, Mass.

Chains (Elevating, Conveying & Power Transmission)
Jointing Compound and Materials
Laboratory Apparatus Reagents and Equipment
Pipe Joint Tools
Sewer Pipe Joints (and Jointing Compounds)

I

Ideal Electric & Mfg. Co.
380 East First Street
Mansfield, Ohio

Motor Controls
Motors

Industrial Chem. Sales Div.
West Virginia Pulp & Paper Co.
230 Park Ave.
New York, New York

Activated Carbon Deodorizing

Infilco Inc.
PO Box 5033
Tucson, Arizona

Acid Feeders
Activated Sludge Plants
Aerators
Automatic Controls
Boiler Feed Treatment Plants
C.-A.-P. SYSTEM® Instruments
Chemical Feeders and Proportioners
Clarifiers
Coagulant Feeders
Coagulators
Clarification Plants
Depth Gauges
Diatomite Filters
Digester Mixing & Heating Equipment
Diffusers
Filter Operating Tables and Consoles
Filter Plant Equipment
Filter Underdrains
Floating Covers
Flotation Equipment
Gas Dispersers
Gauges, Indicating and Recording
Grease and Grit Removal Systems
Griductor Comminutors
Liquid Level Controls and Gauges
Loss of Head Gauges
Manometers
Mixing Equipment
Mobile Water Purification Plants
Pressure Filters
Rate of Flow Controllers and Gauges
Rotagrator Screen and Comminutor
Rotary Distributors
Sampling Tables
Sand Filters
Sewage Treatment Plants
Venturi Tubes and Meters
Wagner Underdrains
Wash Water Controllers
Zeolite Water Softeners

Ingalls Iron Works
Birmingham, Ala.

Steel, Fabricating
Tanks & Standpipes

International Minerals, Inc.
20 N. Wacker Drive
Chicago, Ill.

- Acid Sulfuric and Hydrochloric
- Chlorine, Liquid
- Fluoridation Chemicals

Iowa Valve Co.
201 W. Talman Ave.
Chicago, Ill.

- Hydrants
- Inserting Sleeves Valve
- Meter Accessories, Boxes, Housing, Setting
- Valve Boxes
- Valves, Motor Operated
- Valves, Mud & Plug

J

The Jeffrey Mfg. Co.
884 N. 4th St.
Columbus 16, Ohio

- Aeration Apparatus
- Agitators
- Ash and Coal Handling Machinery
- Bins, Storage
- Castings, Iron, Steel, Alloy Steel, Etc.
- Chains (Elevating, Conveying & Power Transmission)
- Chemical, Conveying Equipment
- Chemical Feeding & Proportioning Equipment
- Clarifiers, Sewage & Water
- Conveyors & Conveying Equipment
- Couplings, Flexible
- Digester Equipment (Sludge)
- Flocculating Equipment
- Grit Chamber Equipment & Grit Washers
- Mixers & Mixing Equipment
- Screens, Intake
- Screens, Sewage
- Screens, Travelig Water
- Screens, Vibrating
- Sludge Collectors
- Sludge Disintegrators
- Sludge Samplers
- Thickeners (Sludge)
- Valves, Check
- Valves, Gate

Johns-Manville Corp.
22 E. 40th St.
New York 16, N. Y.

- Bituminous Coatings and Linings
- Cements, Acid Proof and Alkali
- Cements, Refractory
- Coatings, Acid and Alkali-Proof
- Couplings, and Connections Pipe
- Couplings, Flexible
- Filter Aids
- Gratings, Flooring, Treads, Railings
- Insulation
- Packing (Pumps Joint Valves)
- Pipe and Tank Coatings
- Pipe, Asbestos-Cement
- Pipe, Sewer, Asbestos Cement
- Pipe, Water, Asbestos Cement
- Pipe Wrapping
- Refractories
- Roof Coatings
- Rubber Packing Gaskets

Edward E. Johnson, Inc.
315 N. Pierce Street
St. Paul 4, Minn.

- Diatomite Filter Septums
- Filter Media
- Screens, Water Well
- Screens, River & Lake Reservoir Intake

John Wiley Jones Co.
Caledonia, N. Y.

- Ammonia, Anhydrous & Aqua
- Calcium Hypochlorite
- Chlorine, Liquid
- Taste & Odor Removal Chemicals

K

Keasbey & Mattison Co.
Ambler, Pa.

- Jointing Compound Materials
- Pipe, Asbestos, Cement
- Pipe, Joint Packing

Kerrigan Iron Works, Inc.
1033 Herman St.
Nashville, Tenn.

- Gratings, Floorings
- Treads—Steel, Stainless & Aluminum

S. P. Kinney, Engineers
P. O. Box 445
Carnegie, Pa.

- Valves, Butterfly, Rubber Seated

Komline-Sanderson Eng. Corp.
Peapack, New Jersey

- Drying Systems (Sludge)
- Feeders, Chemical
- Filters, Vacuum
- Meider Collectors
- Pumps, Sludge
- Separation, Flotation
- Sewage Ejectors, Pneumatic

Kuhn Brothers Co.
1800 McCall St.
Dayton, Ohio

- Fittings, Ductile Iron

L

Layne & Bowler, Inc.
1993 Chelsea Ave.
Memphis, Tenn.

- Contractors
- De-Minerialization Equipment
- Drilling & Boring Equipment
- Filter Equipment
- Pumps, Centrifugal
- Pumps, Close Coupled
- Pumps, Deep Well
- Pumps, Hydraulic
- Pumps, Mixed Flow
- Pumps, Propeller
- Pumps, Sewage & Drainage
- Pumps, Submersible
- Pumps, Submersible In-Line
- Pumps, Sump
- Pumps, Turbine
- Water Softening Equipment
- Water Supply, Complete
- Well Casting
- Well Cleaning
- Well Screen
- Wells, Complete

Leeco Chemical Co.
Div. Leeco Gas & Oil Co.
800-71st Street
Miami Beach, Fla.

- Psychoda Fly Control Chemicals

Leupold & Stevens Instruments Inc.
4445 N. E. Glisan
Portland 13, Oregon

- Controllers, Flow, Level, Pressure, Temperature
- Flow Meters
- Gages
- Indicators, Large Dial Illuminated
- Rate of Flow Recorders
- Water Level Controllers
- Water Level Recorders

F. B. Leopold Co., Inc.
227 S. Division St.
Zelienople, Pa.

- Butterfly Valves
- Chemical Feeders
- Contractors
- Fiberglass Reinforced Plastic Wash Water Troughs
- Filter Equipment
- Filter Operating Tables
- Filter Underdrains
- Flocculating Equipment
- Four-Way Valves
- Hydra-Pneumatic Control Systems
- Samplers
- Sampling Tables

Link Belt Co.
Prudential Plaza
Chicago 1, Ill.

- Air Diffusor Units
- Agitators
- Ash Handling Equipment
- Bar Screens
- Bearings, Ball, Babbitted, Roller
- Belt Conveyors
- Bins, Storage
- Bio-Filtration Equipment
- Bucket Elevators
- Car Spotters
- Castings
- Chains and Sprockets (Elevating, Conveying and Power Transmission
- Chemical Feeding and Proportioning Equipment
- Chemical Conveyor Equipment
- Circuline Collectors
- Clarifiers, Sewage & Water
- Collectors, Sludge and Dirt
- Conveyors and Conveying Equipment
- Couplings, Flexible, Rigid and Fluid
- Dryers and Coolers, Sludge
- Drum Screens
- Feeders, Vane
- Flash Mixers
- Flocculation Equipment
- Gearmotors
- Grit Chambers, Collectors and Washers
- Industrial Waste Recovery Equipment
- Liquid Vibrating Screens
- Mixers and Mixing Equipment
- Nozzles, Spray
- Power Transmission Equipment
- Revolving Screens
- Rotary Screens
- Sewage Treatment Equipment
- Screens—Bar, Drum, Revolving, Trash, Sewage, Vibrating, Water In-Take
- Screw Conveyors
- Scum Breakers
- Sludge Collectors
- Speed Reducers
- Straightline Bar Screens and Collectors
- Thickeners (Sludge)
- Trash Screens
- Tritor Screens
- Variable Speed Drives
- Valves, Gate for Bulk Materials
- Vibrating Screens
- Water Intake Screens

Ludlow Valve Mfg. Co.
Ft. of Adams St.
Troy, N. Y.

- Gates, Shear
- Gates, Sluice
- Gate Valve Operator
- Hydrants
- Inserting Sleeves, Valve
- Sleeves, Tapping
- Valve Boxes
- Valves, Air Release & Vacuum Breaking
- Valves, Butterfly
- Valves, Check
- Valves, Flap
- Valves, Float
- Valves, Foot
- Valves, Four Way
- Valves, Mud and Plug

M

A. Y. McDonald Mfg. Co.
12th and Pine Streets
Dubuque, Iowa

- Check Valves
- Copper Service Pipe Couplings
- Corporation Stops
- Curb Boxes
- Curb Stops
- Gate Valves
- Globe Valves
- Goosenecks
- Lead Flange Fittings
- Meter Couplings
- Meter Stops
- Service Boxes
- Service Pipe Couplings
- Solder Nipples
- Water Meter Stop Couplings
- Water Meter Stops

M & H Valve & Fittings Company
P. O. Box 151
Anniston, Alabama

- Hydrants
- Sleeves, Repair
- Sleeves, Tapping
- Valves, AWWA
- Valves, Check
- Valves, Flap
- Valves, Gate
- Valves, Hydraulic
- Valves, Low Pressure
- Valves, Mechanical Joint
- Valves, Motor Operated
- Valves, Mud
- Valves, Pneumatic
- Valves, Ring-Tite/Fluid-Tite
- Valves, Shear
- Valves, Tapping

M. C. G. Company
1851 Bedford Street
Columbus, Ohio

- Filter Underdrains Water

Merrick Scale Co.
184 Autumn St.
Passaic, N. J

- Scales, Sludge

Minneapolis-Honeywell Regulator Co.
Wayne & Windrin Aves.
Philadelphia 44, Pa.

- Boiler Feedwater Treatment and Equipment
- Chemical Feeding and Proportioning Equipment
- Combustion Indicators and Recorders
- Controllers Flow, Level, Pressure, Temperature

Electrical Control Equipment
Filter Equipment
Flow Meters
Gages (Liquid Level, Pressure Recording)
Gas Indicator and Detectors
Manometers
Meteorological Instruments
Meter, Flow Tube
Meters, Gas
Meter Testing Equipment
Meters, Venturi
Operating Tables (Filter)
Orifices
Pumping Controls
Rate of Flow Controllers
Rate of Flow Recorders
Regulators, Pressure (Water and Gas)
Telemetering Equipment
Valves, Chlorine
Valves, Diaphragm
Valves, Motor Operated
Water Level Controllers
Water Level Recorders

Mueller Co.
512 Cerro Gordo St.
Decatur 8, Ill.

Caulking Tools
Clamps & Sleeves, Pipe Clamps, Pipe Repair
Corporation Stops
Corrosion Suppression
Curb Boxes
Curb Stops
Drilling Machines
Fittings, Tees, Ells
Floor Stands
Gates, Shear
Gates, Sluice
Gate Valve Operator
Goose Necks
Hydrants (Fire)
Indicator Posts
Inserting Valves
Laboratory Apparatus
Lubricants, Valve
Meter Accessories
Meter Couplings, Yokes
Pipe, Copper
Pipe Joint Tools
Pipe Tapping Machines
Regulators, Pressure
Saddles, Pipe
Sleeves, Pipe Repair
Sleeves, Tapping
Strainers
Valve Boxes
Valves, Check
Valves, Flap
Valves, Gate
Valve Inserting Equipment
Valves, Mud & Plug
Valves, Pressure Reducing
Valves, Relief
Valves, Tapping

Multiplex Mfg. Co.
Berwick, Pa.

Joints, Slip
Valves, Air Release, Vacuum Breaking
Valves, Sewer
Valves, Surge & Water Hammer

N

Natco Corp.
327 5th Ave.
Pittsburgh 22, Pa.

Ceramic Glazed Facing Tile
Filter Underdrains
Glazed & Unglazed Face Brick
Sewer Pipe
Storage Bins

National Clay Pipe Mfgrs. Inc.
1820 N. St. N. W.
Washington 6, D. C.

Filter Underdrains, Water
Joints, Compression-Type
Pipe, Sewer

National Pool Equipment Co.
Lee Highway, P. O. Box 888
Florence, Ala.

National Power Rodding Corp.
Swimming Pool Equipment & Chemicals

National Power Rodding Corp.
1000 South Western Ave.
Chicago 12, Ill.

Cleaning Sewer Mains
Cleaning Water Mains

Neptune Meter Co.
19 W. 50th St.
New York 20, N. Y.

Meter Parts
Meter Testing Equipment
Meter Valves, Couplings
Meters, Water, Compounds
Meters, Water, Current
Meters, Water, Displacement
Meters, Water, Fire Service
Meters, Water, Recording

Newport News Shipbuilding & Dry Dock Co.
Newport News, Va.

Rack Rakes
Gates, Sluice

Nichols Eng. & Research Corp.
70 Pine Street
New York 5, N. Y.

Driers, Sludge
Incinerators

Norse Electric Co.
55 Water St.
New York, N. Y.

Filters, Diesel Oil
Filters, Engine Oil

O

O'Brien Mfg. Co.
5632 Northwest Highway
Chicago 46, Ill.

Sewer Cleaner Machines

Olin Mathieson Chemical Corp.
Chem. Div.
Mathieson Bldg.
Baltimore 3, Maryland

Acid Sulfuric and Hydrochloric
Ammonia, Anhydrous and Aqua
Calcium Hypochlorite
Chlorine, Liquid
Deodorizing
Soda Ash
Sodium Hypochlorite
Water Treatment for Scale and Corrosion
Well Cleaning Chemicals

The Oliver Corp.
400 W. Madison Street
Chicago 6, Ill.

Earth Moving Equipment
Trenching Equipment

Omega Machine Co.
350 Harris Ave.
Providence 1, R. I.

(See B-I-F Industries Inc.)

Opelika Foundry Co.
P. O. Box 326
Opelika, Ala.

Boxes, Valve
Manhole Covers
Manhole Frames
Meter, Service

OPW-Jordan
6013 Wiehe Road
Cincinnati 13, Ohio

Boxes, curb
Brass goods
Castings
Connections
Controls
Couplings
Fittings
Regulators
Valves:
Air
Automatic
Back Pressure
Check
Control, Temperature and Pressure
Diaphragm
Foot
Gate
Pilot Operated
Pressure Relief
Regulating
Relief, Pressure Vacuum
Water Pressure Reducing, regulating

P

Pacific Flush Tank Co.
4141 Ravenswood Ave.
Chicago 13, Ill.

Aeration Apparatus
Arresters, Flame
Diffusers-Plates, Tubes & Fittings
Digester Equipment
Distributors (Sewage Filter)
Gages (Liquid Level, Pressure Recording)
Gas Holders
Heaters, Digesters
Manometers
Siphons
Trickling Filter Equipment
Valves, Relief
Waste Gas Burners

Pacific Pumping Co.
9201 San Leandro Street
Oakland 3, Calif.

Pumps, Sewage
Pumps, Submersible

Parker Seal Company
Div. Parker-Hannifin Corp.
10567 Jefferson Blvd.
Culver City, Calif.

Gaskets, flange
Seals, flange

Pennsalt Chemicals Corp.
3 Penn Center Plaza
Philadelphia 2, Pa.

Acid Sulfuric and Hydrochloric
Activated Alum
Ammonia, Anhydrous and Aqua
Calcium Hypochlorite
Cements, Acid Proof and Alkali
Chlorine, Liquid
Coagulating Aids
Coatings, Acid and Alkali Proof
Ferric Chloride
Filter Alum
Insecticides
Paint (Acid Resisting)
Sodium Hypochlorite
Sodium Phosphates (Glassy)
Swimming Pool Chemicals

Pennsalt Chem. Corp. Western Div. of Pennsalt Chemicals Corp.
2901 Taylor Way
Tacoma, Washington

Acid Sulfuric and Hydrochloric
Ammonia, Anhydrous and Aqua
Calcium Hypochlorite
Chlorine, Liquid
Ferric Chloride
Insecticides
Sodium Hypochlorite
Sodium Phosphates (Glassy)

Permutit Company
Div. Pfaudler Permutit Inc.
50 W. 44th St.
New York 36, N. Y.

Aerators
Activated Carbon
Automatic Control Tables and Cubicles
Boiler Feedwater Equipment
Chemical Feeders
Carbon Dioxide Indicators and Recorders
Cold Lime and Lime-Soda Process Water Softeners
Deaerators
Demineralizing Equipment
Filter, Gravity and Pressure
Hot Process Water Softeners
Ion Exchange Resins
Iron and Manganese Removal Equipment
Precipitators
Valves, Multiport—Automatic or Manual
Waste Treatment Equipment
Zeolites and Zeolite Water Softeners

Phelps Dodge Refining Corp.
300 Park Ave.
New York, N. Y.

Taste and Odor Removal Chemicals

Philadelphia Quartz Co.
Public Ledger Bldg.
Independence Square
Philadelphia, Pa.

Coagulating Aids
Corrosion Inhibitors
Sodium Silicates

Phipps & Bird Co.
6th & Byrd Sts.
Richmond 5, Va.

Boiler Feedwater Treatment & Equipment
Buffer Solutions & Tablets
Comparators Color
De-Mineralization Equipment (Water)
Laboratory Apparatus Reagents & Equipment
pH Test Equipment
Photoelectric Colorimeters
Pumps, Vacuum
Residual Chlorine Test Apparatus
Samplers & Sampling Tables
Sewage Samplers
Sludge Samplers

Stirrers
Turbidimeters

Photovolt Corp.
95 Madison Avenue
New York, N. Y.
pH Meters

Pittsburgh Coke & Chemical Co.
Grant Building
Pittsburgh 19, Pa.
Coatings, Protective

Pittsburgh-Des Moines Steel Co.
3456 Neville Island
Pittsburgh, Pa.
Bins, Storage
Breechings Steel
Floating Covers
Gas Holders

Portland Cement Assn.
Dearborn & Grand Ave.
Chicago 10, Ill.
Concrete Pipe (Water & Sewage)

Henry Pratt Co.
319 West Van Buren St.
Chicago 7, Ill.
Valves, Butterfly
Valves, Hydraulic Cylinder Operated
Valves, Mechanical Joint

Precision Chemical Pump Corp.
1396 Main St.
Waltham 54, Mass.
Pumps, Chemicals

Preload Corp.
211 E. 37th St.
New York, N. Y.
Bins, Storage
Contractors, Water & Sewage

Pressure Concrete Co.
1555 Helton St.
Florence, Alabama
Gunite Contracting

J. R. Prewitt & Sons, Inc.
Pleasant Hill, Mo.
Drills, Auger
Diggers

Price Bros. Co.
1932 E. Monument Ave.
Dayton, Ohio
Pipe, Concrete, Pressure
Pipe, Culvert
Pipe, Sewer
Saddles, Pipe
Siphons (Sewage Dosing)

Process Engineers, Inc.
420 Peninsular Avenue
San Mateo, Calif.
(See Eimco Corp.)

Proportioneers, Inc.
350 Harris Avenue
Providence 1, R. I.
(See B-I-F Industries Inc.)

R

Rensselaer Valve Co.
Troy, New York
Gates, Sluice
Hydrants (Fire)
Sleeves, Tapping (Valve)
Valves, Flap
Valves, Foot
Valves, Gate
Valves, Hydraulic Cylinder Operated
Valves, Mechanical Joint
Valves, Motor Operated

Roberts Filter Mfg. Co.
640 Columbia Ave.
Darby, Pa.
Boiler Feedwater Treatment & Equipment
Filter Equipment
Filter Underdrains Water
Flocculating Equipment
Operating Tables (Filter)
Sludge Valves (Telescopic)
Valves, Mud and Plug
Water Softening Equipment
Zeolite & Zeolite Softeners

Robinson Pipe Cleaning Co.
Box 300
Canonsburg, Pa.
Cleaning, Sewers
Cleaning, Water Mains

Rockwell Mfg. Co.
400 N. Lexington Ave.
Pittsburgh, Pa.
Lubricants, Valve
Meters, Water
Regulators, Pressure
Valves, Four Way
Valves, Hydraulic Cylinder Operated
Valves, Lubricated Plug
Valves, Mechanical Joint
Valves, Motor Operated
Valves, Mud & Plug

W. S. Rockwell Company
2829 Eliot Street
Fairfield, Conn.
Valves, Butterfly
Valves, Check
Valves, Cylinder Operated
Valves, Diaphragm Disc
Valves, Float
Valves, Motor Operated
Valves, Slide

Roots-Connersville Blower
Div. of Dresser Industries, Inc.
900 West Mount St.
Connersville, Ind.
Blowers, Aeration, positive
Blowers, Aeration, centrifugal
Meters, Gas
Pumps, vacuum filter

Royer Foundry & Mach. Co.
158 Pringle Street
Kingston, Pa.
Sludge Disintegrators

S

Schield Bantam Co.
Park Street
Waverly, Iowa
Trenching and Construction Equipment

Schramm, Inc.
West Chester, Pa.
Air Compressors, Portable
Air Compressors, Self-Propelled
Air Compressor, Tractor-Type
Construction Tools
Pump, Sump

Shahmoon Industries, Inc.
Warren Foundry & Pipe Div.
55 Liberty St.
New York 5, N. Y.
Pipe, Cast Iron

Simplex Valve & Meter Co.
7 E. Orange Street
Lancaster, Pa.
Controllers Flow, Level, Pressure, Temperature
Filter Equipment
Gages (Liquid Level, Pressure Recording)
Indicators, Large Dial Illuminated
Manometers
Meters, Electric
Operating Tables (Filter)
Orifices
Rate of Flow Controllers
Rate of Flow Recorders
Sand Expansion Indicators
Valves, Air Release & Vacuum Breaking
Venturi Tubes
Water Leak, Locating Instruments
Water Level Controllers
Water Level Recorders

Smith-Blair, Inc.
535 Railroad Ave.
So. San Francisco, Calif.
Adapters, Flanged Coupling, Mechanical Joint
Caps, Pipe End
Clamps, Pipe Repair
Couplings, Mechanical Joint Straight & Reducing
Fabrications, Pipelines
Joints, Expansion
Rings, Water Lock
Saddles, Tapping, Repair
Sleeves, Tapping
Tees, Cast

A. P. Smith Mfg. Co.
East Orange, N. J.
Pipe Test Plugs
Sleeves, Tapping (Valve)
Valve Boxes
Valve Inserting Machines
Valves, Check
Valves, Gate
Valves, Hydraulic Cylinder Operated
Valves, Mechanical Joint
Valves, Motor Operated

Smith & Loveless, Inc.
96th St. & Old 50 Highway
Lenexa, Kansas
Chlorinators
Distributors, Rotary
Filters, Swimming Pool
Recarbonators
Sewage Ejector Stations
Sewage Pumping Stations
Sewage Pumps
Sewage Treatment Plants
Water Mixers, Flocculators
Water Pumping Stations

Southwestern Plastic Pipe Co.
P. O. Box 117
Mineral Wells, Texas
Pipe, Plastic

Sparling Meter Company
225 North Temple City Blvd.
El Monte, California
Batch control totalizers
Controls, auto metered
Indicators, rate of flow
Indicators-Totalizers, rate of flow
Indicators-Totalizers, water level
Indicators, water level
Meters, Compound
Meters, Fire Hydrant
Meters, Main-line propeller type
Meters, Saddles Bolting Saddles Welding
Meters, Salt Water
Meters, Water Works Intake
Totalizers

Speelmon Elevated Tank Service
822 N. Court Street
Rockford, Ill.
Tank Linings
Tank Maintenance & Repair

J. S. Staedler, Inc.
25 Dicarolis Court
Hackensack, N. J.
Drafting Pencils
Drafting Leads
Drafting Lead Holders

Standard Dry Wall Products, Inc.
Box X
New Eagle, Pa.
Concrete Hardener
Pipe, Cement Lining of
Waterproofing Paints, Compounds, and Materials

Standard Instrument Corp.
657 Broadway
New York 12, N. Y.
Recorders
Totalizers

Standard Steel Corp.
5067 S. Boyle Ave.
Los Angeles 58, Calif.
Drying Systems, Sludge

Steel Plate Fabricators Assn.
105 W. Madison St.
Chicago 2, Ill.
Pipe, Steel
Tanks, Steel

Stuart Corp.
516 N. Charles St.
Baltimore, Md.
Activated Carbon
Anthrafilt
Ash & Coal Handling Machinery
Conveyors & Conveying Equipment
Filter Equipment
Filter Media
Filter Underdrains, Water
Flocculating Equipment
Gates, Sluice
Grit Chamber Equipment & Grit Washers
Mixers & Mixing Equipment
Water Softening Equipment

Synchro Start Products, Inc.
8151 N. Ridgeway
Skokie, Ill.
Electrical Control Equipment
Engine Controls

T

Tennessee Corp.
619 Grant Bldg.
Atlanta, Ga.

Acid Sulfuric & Hydrochloric
Copper Sulfate
Dechlorinating Equipment & Chemicals
Ferric Sulphate
Fluoridation Chemicals
Thickeners (Sludge)

U

U. S. Electrical Motors, Inc.
200 E. Slauson Ave.
Los Angeles 54, Calif.

Gears, Speed Reducing
Motors, Electric
Speed Reducers, Transmission
Variable Speed Transmissions

U. S. Pipe & Foundry Co.
3300 First Ave. N.
Birmingham 2, Ala.

Cement Lined Pipe and Fittings
Fittings, Pipe
Pipe, Centrifugal Cast Iron
Pipe, Tyton Joint®
Pipe, Mechanical Joint
Pipe, Bell-and-Spigot
Pipe, Flanged
Pipe, Flexible Joint

U. S. Rubber Co.
1230 Avenue of Americas
New York 20, N. Y.

Acid, Sulphuric & Hydrochloric
Chemical, Conveying Equipment
Clamps & Sleeves, Pipe
Coatings, Acid & Alkali-Proof
Couplings, Flexible
Filter Aids
Forms & Gaskets for Pipe Joints
Hose, Air, Steam, Water, Suction
Insecticides
Joints, Expansion Pipe
Lubricants, Valve
Paint (Acid Resisting)
Pipe & Fittings Lined
Pipe & Tank Coatings
Pipe Joints (Mechanical)
Pipe, Plastic
Roof Coatings
Rubber Lined Pipes & Valves
Tank Linings
Tanks, Rubber Lined
Valves, (Rubber, plastic, glass or lead)
Waterproofing Paint, Compounds & Materials
Weed Killers
Well Cleaning Chemicals

V

Vulcan Materials Co.
2019 Sixth Ave. N.
Birmingham, Ala.

Aggregates

W

W-K-M Division of
ACF Industries, Inc.
PO Box 2117
Houston 1, Texas

Valves, Ball
Valves, Check
Valves, Lubricated plug
Valves, Motor Operated
Valves, Special Automatic

E. H. Wachs Company
1525 N. Dayton Street
Chicago, Ill.

Saws, Pipe
Tools, Pipe

Walker Process Equipment Inc.
840 N. Russell Ave.
Aurora, Ill.

Aeration Apparatus
Carbonators
Clarifiers, Sewage and Water
Digester Equipment, Sludge
Distributors, Sewage
Floating Covers
Flocculating Equipment
Gas Diffusers
Gas Holders
Grinders, Garbage and Screenings
Grit Chamber Equipment and Grit Washers
Heaters, Digester
Mixers and Mixing Equipment
Package Sewage Treatment Plants
Samplers and Sampling Sinks, Sewage
Screens, Sewage
Sludge Collectors
Thickeners, Sludge
Trickling Filter Equipment
Valves, Sludge
Water Softening Equipment

Wallace & Tiernan Inc.
25 Main St.
Belleville, N. J.

Ammoniators
Activated Silica Equipment
Boiler Feedwater Treatment and Equipment
Chemical Control Equipment
Chemical Feeding and Proportioning Equipment
Chlorinators
Chlorine Control Equipment
Comparators
Dechlorinating Equipment & Chemicals
Gages (Liquid Level, Pressure, Recording)
Gas Indicators & Detectors (Chlorine)
Hypochlorinators
Hydrogen-Ion Equipment
Lime Slakers
Manometers
pH Test Equipment
Proportioning Equipment
Pumps, Acid Handling
Pumps, Diaphragm
Regulators, Pressure (water & gas)
Residual Chlorine Controllers
Residual Chlorine Test Apparatus
Valves, Chlorine
Water Level Recorders
Water Treatment for Scale & Corrosion

Washington Aluminum Co.
Knecht Ave. & Penn R. R.
Baltimore, Maryland

Gates, Shear
Gratings, Flooring Treads, Railings

Water Seals, Inc.
9 S. Clinton St.
Chicago 6, Ill.

Waterstops

Waukesha Motor Co.
Waukesha, Wisc.

Engines, Gas, Gasoline, LP Gas, Sewage Gas

Weinman Pump Mfg. Co.
286 Spruce Street
Columbus, Ohio

Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Sewage & Drainage
Pumps, Sump (& cellar drainer)

Westinghouse Electric Corp.
Gateway Center, 401 Liberty Ave.
Pittsburgh 30, Pa.

Electrical Control Equipment
Fans Exhaust & Ventilating
Furnaces (Melting, Pouring, Ladles, Pots, etc.)
Gears, Speed Reducing
Generators (Electric)
Meters, Electric
Motors, Electric
Penstocks
Pipe, Plastic
Switchboard & Switch Gear
Transformers, Electric
Turbines, Steam
Valves, Butterfly
Valves, Gate
Valves, Motor Operated

Wheeler Manufacturing Corp.
80 Ross Road
Ashtabula, Ohio

Pipe Cutters
Pipe Tools

C. H. Wheeler Mfg. Co.
19th & Lehigh Sts.
Philadelphia 32, Pa.

Pumps, Centrifugal
Axial and Mixed Flow
Mixed Flow Volute
Sewage and Drainage
Sump
Vacuum
Valve Operators

White Motor Co.
White Diesel Engine Div.
1401 Sheridan
Springfield, Ohio

Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines, Gas & Gasoline
Engines, Sludge, Gas

Wilbur & Williams Co., Inc.
662 Pleasant Street
Norwood, Mass.

Paints
Protective Coatings

John Wiley & Sons, Inc.
440 4th Ave.
New York 16, N. Y.

Books, Technical

R. D. Wood Co.
Public Ledger Bldg.
Philadelphia 5, Penna.

Fittings, Tees, Ells, Etc.
Hydrants (Fire)
Pipe, Cast Iron
Pipe, Cement Lined
Pipe, Culvert
Pipe Joints (Mechanical)
Valve Boxes
Valves, Gate
Valves, Mechanical Joint

Woodward Iron Co.
Woodward, Alabama

Pipe, Cast Iron

Worthington Corp.
Harrison & Worthington Aves.
Harrison, N. J.

Agitators
Comminuting Devices
Compressors, Air
Concrete Breakers
Concrete Mixer
Condensers (Steam)
Drilling & Boring Equipment
Drives, V-Belt
Ejectors, Pneumatic or Steam
Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines (Gas & Gasoline)
Engines, Sludge, Gas
Gears, Speed Reducing
Generators (Electric)
Mixers & Mixing Equipment
Motors, Electric
Nozzles, Spray (Water & Sewage)
Orifices
Pumps, Acid-Handling
Pumps, Centrifugal
Pumps, Deep Well
Pumps, Hydraulic (Pressure Boosting)
Pumps, Portable
Pumps, Self-Priming
Pumps, Sewage & Drainage
Pumps, Sludge
Pumps, Sump (And Cellar Drainer)
Pumps, Turbine
Pumps, Vacuum
Switchboard & Switch Gear
Tools, Pneumatic
Turbines, Steam
Valves, Butterfly
Valves, Gate
Variable Speed Transmissions

Y

Yeomans Bros. Co.
1999 N. Ruby St.
Melrose Park, Ill.

Aeration Apparatus
Clarifiers, Sewage & Water
Compressors, Air
Digester Equipment
Distributors, Sewage Filter
Ejectors, Pneumatic or Steam
Nozzles, Spray, Water & Sewage
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Sludge
Pumps, Sewage & Drainage
Pumps, Vacuum
Pumps, Sump and Cellar Drainer
Trickling Filter Equipment

Z

Zimmer & Francescon
Moline, Illinois

Pumping Stations, Sewage

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